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ENGINEERING:

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Birkenhead.
See Illustrated Advertisement Page 100, Jan. 28.

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See page 17, Dec. 2. 9108

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Specification and Workmanship equal to Main Line Locomotives.
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Sole Licensees in Great Britain for the manufacture of "Armco" Rust and Corrosion Resisting Iron Tubes. 8746
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CARDIFF WAREHOUSE—132, BUTE ST.
BIRMINGHAM WAREHOUSE—NILE STREET, SHEEPSCOTE STREET.
See Advertisement, page 26. 9091

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&c. &c. 9604

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(ELECTRIC).
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Patent
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Great saving of labour. No noise. No dust. No dirt. Ashes discharged 20 ft. clear of vessel.—Apply, F. J. TREWENT & PROCTOR, LTD., Naval Architects and Surveyors, 43, Billiter Bldgs., Billiter St., London, E.C. Od 4835

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STILLS, PETROL TANKS, AIR RECEIVERS, STEEL CHIMNEYS, RIVETTED STEAM and VENTILATING PIPES, HOPPERS, SPECIAL WORK, REPAIRS OF ALL KINDS.

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See Advertisement page 65, Dec. 2. 2402

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Also 2-500 Kw. PARSONS TURBINE SETS, 250 or 500 Volts D.C., with Condenser and spare armature.
ELECTRICALLY DRIVEN AIR COMPRESSORS, 250 Volts D.C. Pressures 1000 to 3000 lbs. per square inch.
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Gas Engines Inspected, Tested and Reported Upon. Over 25 years' experience. Tel.: 736 and 737 Stratford. Wire: "Rapidling, London." —Great Eastern Road, Stratford, E. 15. 1794

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See half-page Advertisement page 76, Nov. 25.

See Advt. Page 93 Dec. 2.
Steam Hammers
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For the prevention of Steam Boiler Explosions and for the attainment of Economy in the Application of Steam. 9, MOUNT STREET, MANCHESTER.

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Founded 1854 by SIR WILLIAM FAIRBAIRN.

Certificates of Safety issued under the Factory and Workshops Act, 1901. Compensation for Damages and Liabilities paid in case of Explosions. Engines and Boilers inspected during construction. 9310

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EXCAVATING AND MINING MACHINERY MAKERS

of South Milwaukee, Wisconsin, U.S.A., and formerly represented in the British Isles by Messrs. G. F. West & Co., wish to announce that they have now Opened their Own Office at

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9741

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B.Sc., Inst. C.E., I. Mech. E., all ENGINEERING EXAMS. Special Courses and Single Subjects. Personal tuition.—For full particulars apply to MR. TREVOR W. PHILLIPS, B.Sc. (HONS.), Assoc.M.Inst.C.E., M.R.S.I., etc., 8-10, Trafford Chambers, 58, South John Street, Liverpool. 9296

Inst. C.E., I. Mech. E., B.Sc.,

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TENDERS.

THE HIGH COMMISSIONER FOR INDIA is prepared to receive

Tenders for the Supply

of:—

PLATES, COPPER, FIREBOX, FLANGED.

Forms of Tender may be obtained from the Director-General, India Store Department, Belvedere Road, Lambeth, S.E. 1, and Tenders are to be delivered at that Office not later than Two o'clock p.m. on Tuesday, the 20th December, 1921.

T. RYAN, S 801
Director-General.

METROPOLITAN BOROUGH OF SHOREDITCH.

ELECTRICITY SUPPLY DEPARTMENT.

Tenders are Invited for the

SUPPLY, DELIVERY and ERECTION of ONE WATER TUBE BOILER of 33,000 lbs. evaporative capacity.

Specification, Form of Tender, and full particulars may be obtained upon application to the undersigned and on payment of deposit of £1, which will be returned upon receipt of *bona fide* Tender.

Sealed Tenders, endorsed "Tender for Boiler Plant," must be delivered at the Town Clerk's Office, Town Hall, Shoreditch, E.C. 2, not later than noon, on the 3rd January next.

C. NEWTON RUSSELL,
Borough Electrical Engineer.

Electricity Supply Department,
Coronet Street,
Shoreditch, N. 1. S 831

THE SOUTH INDIAN RAILWAY COMPANY LIMITED, are prepared to receive

Tenders for the Supply of:

(1) 90 lb. STEEL RAILS and FISHPLATES (about 4700 tons).
(2) C. I. SLEEPERS for 90 lb. Rails (about 4900 tons).
(3) TIE BARS, GIBS and COTTERS for ditto (about 1000 tons).
(4) COILED STEEL KEYS for ditto.
(5) 40 lb. STEEL RAILS and FISHPLATES (about 2700 tons).

Specifications and Forms of Tender will be available at the Company's Offices, 91, Petty France, Westminster, S.W. 1.

Tenders, addressed to the Chairman and Directors of the South Indian Railway Company, Limited, marked "Tenders for Rails and Fishplates," or as the case may be, must be left with the undersigned not later than Ten a.m., on Monday, the 19th December, 1921.

The Directors do not bind themselves to accept the lowest or any Tender.

A charge, which will not be returned, will be made of 40s. for each copy of Specification No. 2, and 20s. for each copy of Specifications Nos. 1, 3, 4, and 5.

Copies of the Drawings may be obtained at the Office of Messrs. ROBERT WHITE & PARTNERS, Consulting Engineers to the Company, 3, Victoria Street, Westminster, S.W. 1.

W. B. REYNOLDS,
for Managing Director.

91, Petty France, S.W. 1.
7th December, 1921. S 848

WINCANTON RURAL DISTRICT COUNCIL.

TEMPLECOMBE WATER SUPPLY.
CONTRACT No. 1.

The above Council invite

Tenders for the Supplying,

TRENCHING, LAYING and JOINTING of about 7,300 yards of 6 inches, 4 inches, 3 inches and 2 inches CAST IRON, etc., WATER MAINS; the CONSTRUCTION of a WELL, PUMPING STATION, REINFORCED CONCRETE SERVICE RESERVOIR, etc., and other works incidental thereto, in accordance with Plans and Specifications prepared by the Engineers, Messrs. A. P. I. COTTERELL AND ESSON, of 17, Old Queen Street, Westminster, S.W. 1.

Plans and Specification may be seen at the office of the Engineers, 17, Old Queen Street, Westminster, on or after the 9th December, 1921, or at the office of the undersigned, during usual office hours.

Copies of the Bills of Quantities and Form of Tender may be obtained from the Engineers on or after the 9th December, 1921, by intending Contractors on payment of the sum of Five Guineas which will be returned on receipt of a *bona fide* Tender and all other documents supplied.

Tenders on the Form provided, enclosed in sealed envelopes must be delivered to the undersigned and endorsed "Templecombe Water, Contract No. 1," not later than Ten a.m., on the 27th December, 1921.

Contractors will be required to provide securities for the due performance of the Contract under Section 174 (4) of the Public Health Act, 1875.

The Council do not undertake to accept the lowest or any Tender, but reserve freedom of action.

By Order,
R. N. MARTIN,
Clerk to the Rural District Council.

Wincanton,
3rd December, 1921. S 824

LONDON COUNTY COUNCIL.

TRAMWAY SUPPLIES, ELECTRICAL EQUIPMENT, ETC.

Applications are Invited from

Firms, and particularly Manufacturers, for permission to be placed on the lists of persons and firms from whom the Council from time to time invites TENDERS for the SUPPLY of the UNDERMENTIONED FITTINGS, ELECTRICAL and MECHANICAL EQUIPMENT and SPARES, etc., required for the Council's Tramways:—

Class No.
1. Car Motors, complete and spares.
2. Coils Armature, Field and Magnetic Brake.
3. Gear and Pinion Wheels.
4. Armature Rewinding and Repair.
5. Machined Bronze Bearings.
6. Machine finished Articles (Brass, Gunmetal, etc.)
7. Do. Do. (Iron, Steel, etc.).
8. Iron and Steel Drop Forged Stampings.
9. Iron and Steel Forgings.
10. Springs for Electric Car Trucks.
11. Iron Castings, machined and not machined.
12. Brake Shoes for Electric Car Trucks.
13. Malleable Iron Castings, machined and not machined.
14. Steel Castings, machined and not machined.
15. Truck Sides.
16. Castings, Brass, Gunmetal, Phosphor Bronze, Aluminium.
17. Whitemetal and Bearing Alloys.
18. Rolled Steel Bars for Magnetic Brake Shoes.
19. Channels, Angles and Special Sections.
20. Tyres, Steel for Tramcars,
21. Car Controllers complete and Spares.
22. Controller Fingers, Segments, etc.
23. Canopy Switches, Circuit Breakers and Spares.
24. Rheostats, complete and Spares.
25. Pressed Brass and Steel Articles.
26. Carbon Brushes for Tramcar Motors and Generators, etc.
27. Wire, Copper, Cotton covered.
28. Cable, Electric.
29. Car Furniture and Fittings.
30. Moulded Rubber Articles.
31. Moulded Insulators (other than Rubber).
32. Fibre Articles.
33. Mica and Micanite Articles.
34. Press-spahn.
35. Insulating Varnishes.
36. Foundry Crucibles and Requisites.
37. Transfers Coachpainters,
38. Tyres, Rubber for Motor Vehicles,
39. Electrical Line Equipment (Overhead).
40. Do. Do. (Conduit).
41. Copper Bonds.
42. Acetylene Generators and Lamps.
43. Welding Work.
44. Welding Plant and Electrodes.
45. Stone Crusher Rolls, Jaws, etc.
46. Granite Sets.

Applications must be made on the official form, copies of which, together with a statement giving further information on the subject, including the standard conditions of contract, may be obtained from the General Manager, Tramways Department, 23, Belvedere Road, S.E. 1.

In those cases in which Tenders are limited to manufacturers or producers, applications from agents, middlemen, or dealers, will not be considered.

Firms making application for inclusion in the selected lists of Tenderers, will be informed in due course of the Council's decision in the matter.

Attention is drawn to the fact that, in cases in which the name of a person or firm has been placed on the Council's lists, it is not necessary for such person or firm to apply for form of Tender, as in all suitable cases forms of Tender will be sent from time to time as issued.

Applications for inclusion in the first lists of selected firms for the supply of the goods and articles enumerated above must be sent in not later than 31st December, 1921. Applications received thereafter will receive consideration in connection with future supplies.

JAMES BIRD,
Clerk of the London County Council.

S 709

G. R.

FLOATING DOCK FOR SALE WITHOUT RESTRICTION AS TO TRANSFER ABROAD.

The Admiralty have Available

FOR SALE a 600 tons ex-German FLOATING DOCK at present lying at Sheerness.

Facilities for inspection together with Forms of Tender, &c., may be obtained upon application to the DIRECTOR OF NAVY CONTRACTS, Branch 8, Admiralty, Princes House, Kingsway, London, W.C. 2.

Tenders are due at the Admiralty by Noon on Friday, 30th December. 1921. S 805

EAST INDIAN RAILWAY.

The East Indian Railway Company is prepared to receive

Tenders for the Supply and

DELIVERY of:—
(1) INDIA-RUBBER SHEETING, &c.
(2) WHEEL LATHES,

as per Specifications to be seen at the Company's Office.

Tenders are to be sent to the undersigned, marked "Tender for India-rubber Sheeting, &c.," or as the case may be, not later than Eleven o'clock a.m., on Wednesday, the 21st day of December instant

The Company reserves to itself the right to divide the order, also to decline any Tender without assigning a reason and does not bind itself to accept the lowest or any Tender.

For each specification a fee of £1 1s. is charged, which cannot under any circumstances be returned.

By Order,
G. H. LILLIE,
Secretary.

Nicholas Lane, London, E.C. 4.
7th December, 1921. S 862

THE GREAT INDIAN PENINSULA RAILWAY COMPANY.

The Directors are prepared to receive

Tenders for the Supply of

the following STORES, namely:—

		Fee for Specification.
No. 1.	Crank Axles and Straight Axles	10/-
No. 2.	Wheels and Axles	£1
No. 3.	Rolled Steel Disc Wheels	10/-
No. 4.	Brass and Iron or Steel Screws	5/-
No. 5.	Plate Glass, &c.	10/-

Specifications and Forms of Tender may be obtained at this office on payment of the fee for the Specification, which payment will not be returned.

The fee should accompany any application by post. Cheques and Postal Orders should be crossed and made payable to the Great Indian Peninsula Railway Company.

Tenders must be delivered in separate envelopes, sealed and addressed to the undersigned, marked "Tender for Crank Axles and Straight Axles," or as the case may be, not later than Eleven o'clock a.m., on Tuesday, the 20th December, 1921.

The Directors do not bind themselves to accept the lowest or any Tender.

R. H. WALPOLE,
Secretary.

Company's Offices,
48, Copthall Avenue, E.C. 2.
London, 7th December, 1921. S 863

APPOINTMENTS OPEN.

RESEARCH DEPARTMENT,
ROYAL ARSENAL, WOOLWICH.

DIRECTORATE OF RADIOLOGICAL RESEARCH.
ASSISTANTS II.

Required, One Assistant

II. Candidates should possess honours degree in Physics and at least two years' research experience.

Initial salary £280 and bonus (Total emoluments at present approximately £450).

Annual leave, six weeks.

Applications in writing, with copies of testimonials and references to any published work should be made to the

CHIEF SUPERINTENDENT,
Research Department,
Royal Arsenal,
Woolwich,

from whom the conditions of Employment may be obtained. S 816

SWINDON AND NORTH WILTS TECHNICAL INSTITUTION.

Principal:—G. H. BURKHARDT, M.A. M.Sc.

Applications are Invited for

the following POSTS from graduates in Engineering, who are able to take up the duties in January next. Both works experience and teaching experience are essential:

(1) HEAD OF ENGINEERING DEPARTMENT, who should be well-qualified in Mechanical Engineering.
Salary according to Burnham Scale with initial addition of £30 per annum for special responsibility and three-quarter "carry-over" as from September 1921.
(2) ASSISTANT LECTURER IN ENGINEERING, who should be well-qualified in Electrical work.
Salary according to Burnham Scale with three-quarter "carry-over" as from September, 1921.

Further particulars and forms of application (to be returned not later than the 17th December) may be obtained from the PRINCIPAL, Technical Institution, Swindon.

W. SEATON,
Secretary. S 825

COUNTY BOROUGH OF CROYDON.
EDUCATION COMMITTEE.

Wanted, Teacher of Machine

Construction, Wednesday Evenings, 7.30 to 9.30 from January 11th. Fee 21s. per attendance. State full particulars of education, training, age, experience, and present appointments, to the PRINCIPAL, Central Polytechnic, Scarbrook Road, Croydon.

JAMES SMYTH,
Clerk to the Committee.
5th December, 1921. S 837

UNIVERSITY OF LONDON—GOLDSMITHS' COLLEGE, NEW CROSS, S.E. 14.

Applications are Invited for

the POST of PART-TIME LECTURER in Electrical Engineering (Grade—City and Guilds Final Examination). Applicants should possess a good honours degree in Engineering and should have had good practical experience. Remuneration in accordance with the London County Council's Scale.

Applications should be made by letter, stating qualifications, to the WARDEN, Goldsmiths' College, New Cross, S.E. 14. S 832

Machine Tools:—Manager

REQUIRED by firm employing 500 men engaged solely upon building special machine tools. Only energetic men of suitable experience, who possess tact, have organising ability and initiative need apply. Position is permanent and holds prospects.—Address, S 812, Offices of ENGINEERING.

Wanted, Manager for an

Indian Colliery (Bengal), with first class certificate. Five years' agreement. House provided in healthy district. Good prospects for a suitable man. Salary commencing at Rs. 600 per month.—Write, giving full particulars of experience, age, references, etc., to Z. K. 308, c/o DEACONS, Leadenhall Street, London, S 835

Works Manager. — Post

WANTED in progressive concern by live man who can introduce new methods to effect REAL economy in production. Special ability in design and D.O. Control. Good knowledge of commercial engineering, cost accountancy, etc.—Address, S 859, Offices of ENGINEERING.

Wanted, Experienced Ma-

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HOPKINSON (Valves and Boiler Mountings) 94, Rue St. Lazare, PARIS, as Assistant to Manager. Applicants must be British, age 28 to 35, with technical and commercial experience, general knowledge steam power plants, and good French. — Applications by letter, giving all particulars and salary required. S 758

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Book-keeping experience REQUIRED for Engineering repair works. Give full particulars, age, experience and salary.—Address, S 833, Offices of ENGINEERING.

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WANTED, familiar with Coke Oven and Gas Retort Plant, must be capable of getting out sizes of Carbonising and By-Product Plants, state age and salary required. — Address, S 811, Offices of ENGINEERING.

THE MANUFACTURE OF CRANKSHAFTS.

THE crankshaft of a reciprocating engine or pump is not only the most difficult and expensive part to manufacture, but is a component upon whose excellence the satisfactory behaviour of the machine will very largely depend. The making of crankshafts calls for methods of manufacture which are peculiar to the class of work in question. The forging processes are in general of a heavier nature than those involved in the production of any other part of an engine, and as only one crankshaft is required for every engine built, it is rarely that a firm of engine builders has an output sufficiently large to warrant them in providing the equipment necessary to forge their own crankshafts. For this reason it has been customary among engine builders to purchase crankshaft forgings from outside firms, who, by specialising in their production, can manufacture them better and more cheaply than they could be produced in a general smithy. Forgings supplied in this way would generally be delivered in a rough-machined state, especially where the larger sizes are concerned, because the rough-machining would not only disclose any cracks and surface defects which might exist, but would also prove beyond question that a sufficient machining allowance had been left on every part of the surface. It was then but a small step for the engine builder to purchase his crankshafts in a finished condition from the crankshaft maker, thus avoiding the expense of double machining and saving himself the trouble of a series of somewhat difficult and specialised machining operations. This is the practice which is now very largely adopted by engine builders, and several firms have, in consequence, laid themselves out to supply the demand for crankshafts, these being delivered either completely finished or as forgings.

One of the earliest firms to specialise in crankshaft production was Messrs. Clarke's Crank and Forge Company, Limited, of Lincoln, who started a forge on the site of their present works in 1859. This was a period of great development of portable and traction engines for agricultural purposes, and Lincolnshire was then, as now, one of the most important centres of this branch of engineering industry. Messrs. Clarke's Crank and Forge Company, Limited, soon established a prosperous business in the bending of shafts for the local engine makers. The reputation of the firm gradually extended, and engine builders in other parts of the country and abroad began to place orders in Lincoln for the crankshafts they needed. During the first fifty years of the firm's existence, however, little progress was made in the matter of extensions to buildings or equipment, and although a considerable amount of special work was done, the mainstay of the factory was the supply of cranks to the local agricultural engineers and the manufacture of forgings up to about a ton in weight. In the year 1909 the company was reconstructed, and Mr. Louis W. Smith, who then acquired a large financial interest in it, resolved to rebuild the works and to equip them with the most modern and efficient plant available. It was necessary, moreover, to do this without interfering with the manufacturing processes, so that the work had to be carried out piecemeal. In accordance with Mr. Smith's plans, the new shops were built over the old ones, the latter being replaced section by section as the work proceeded. Some ten or twelve years have been occupied in making the change, and the works now consist of modern steel buildings with electric cranes and other appliances for economical manufacture. With only one or two exceptions the whole of the plant in the forge and machine shops has been replaced by modern machinery, laid out with the idea of reducing transport of material to the minimum possible. The light work and the heavy work each has its appointed path through the machine shops, along which it travels without retrogression.

A section and plan of the works as at present constituted are given in Figs. 1 and 2, subjoined. The offices front on Coultham-street, and at the back of the works are the lines of the Great Northern and Great Eastern Railways, from which spur-tracks enter the yard and diverge to serve the various shops. These tracks are connected to narrow-gauge rails, which serve the individual machines and provide a means of internal transportation for the heavier work. Just about half the area of the works is allocated to forging and other smith's work. The heavy forge contains a 1,200-ton high-speed steam-hydraulic forging press by Davy Brothers, Limited, of Sheffield, and a three-ton steam hammer by the same makers. The two machines are served by a 30-ton and a 10-ton overhead crane, and by six furnaces, each with its own waste-heat boiler. These boilers, together with the other waste-heat boilers in the light forge, supply practically the whole of the steam required for the hammers and for heating the works, a little being contributed by a Lancashire boiler fired chiefly with refuse fuel from the furnaces. The main duty of this boiler is to supply steam for heating the works during periods when the furnaces are not in operation.

A general view of the heavy forge, with the 1,200-ton press in the foreground, is shown in Fig. 3, page 778. This press, which has a stroke of 4 ft., works with a water pressure of 2·5 tons per square inch, furnished by a steam intensifier. The overall height above ground level is 20 ft., and the columns, which are spaced at 8 ft. centres when looked at from the front of the press, and at 3 ft. 9 in. centres

SECTIONAL ELEVATION.

Fig. 1.

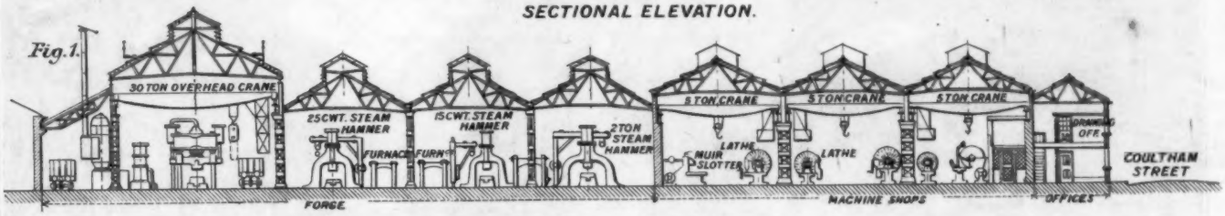
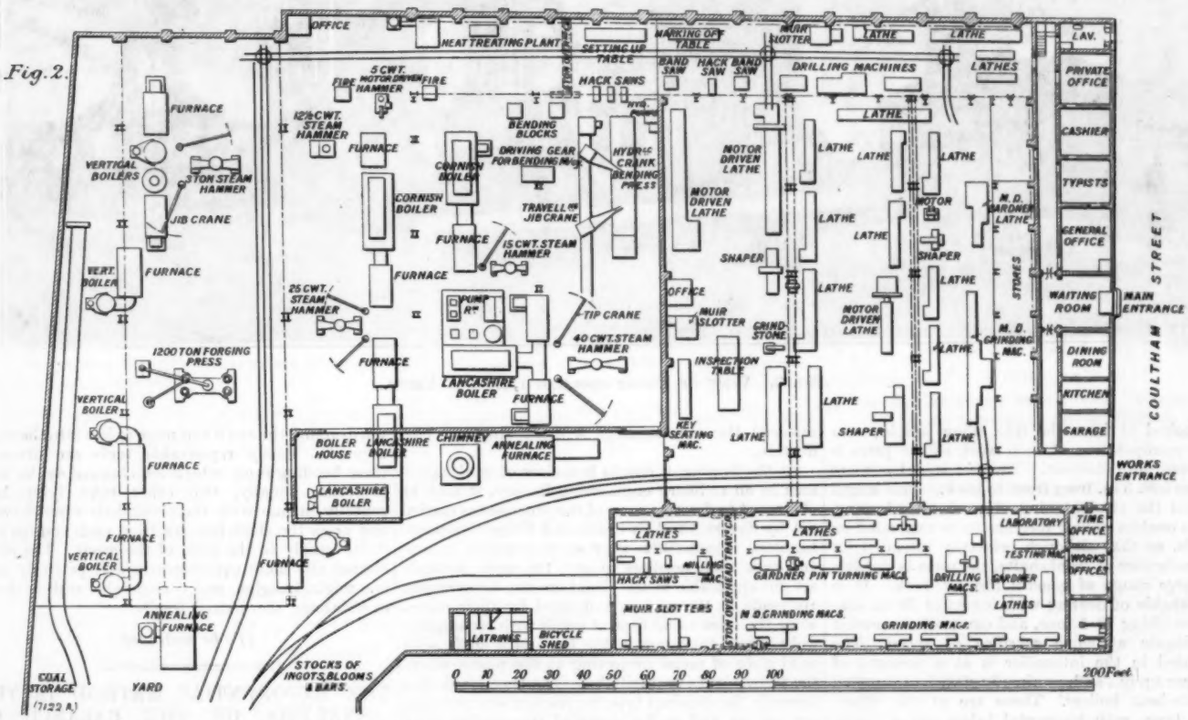


Fig. 2.



THE WORKS OF MESSRS. CLARKE'S CRANK AND FORGE CO, LTD., LINCOLN.

Fig. 3. View of Forge showing 1,200-Ton Press.

when looked at from the side, allow ample room for the manipulation of such work as the press is called upon to undertake. The cast steel baseplate measures 9 ft. 3 in. from front to back. This length facilitates the straightening of work after forging, and also enables hollow forgings to be expanded on mandrels, so that although primarily intended for the manufacture of crankshafts, the press is suitable for a large range of general forging work. It is easily capable of dealing with ingots of 30 in. diameter, weighing 10·5 tons, and can work somewhat larger ingots at some sacrifice of speed. The steam used in the intensifier is at a pressure of 150 lb. per sq. in., and, as already stated, is supplied by waste-heat boilers. These are of the Blake vertical type, with horizontal tubes and a "wet-back" combustion chamber. Each boiler has an auxiliary grate, for hand-firing when necessary, but normally the waste gases from the furnaces will raise all the steam required. With gases leaving the furnaces at a temperature of from 1,500 deg. F. to 2,250 deg. F., the boilers will generate from 3·5 lb. to 5·5 lb. of steam for every pound of coal used in the heating furnaces.

The general appearance of the machine shops will be gathered from Figs. 4 to 8 on Plate XLIII The larger lathes, such as that shown in Fig. 4, are driven by their own motors, so that shafting and belting are avoided and the crane service to the lathe greatly facilitated. The well-lighted and modern appearance of the shops are well shown in the photographs, and are in great contrast to the conditions existing before their reconstruction. Fig. 9, on Plate XLIII, is of special interest, as it shows the last remnant of the old machine shops and indicates the thorough-going method of reconstruction. Part of the old wall, together with some roof principals, are seen entirely covered by the loftier modern structure, which, as we have already mentioned, replaced the old buildings without stopping production.

As the forging of cranks is a class of work rarely seen in an ordinary engineering factory, it may be of interest to describe some of the processes as carried out by Messrs. Clarke's Crank and Forge Company, Limited. Crankshafts vary so very widely in size and type that, needless to say, the same methods are not applicable to all. Bent cranks, for example, are made in the manner indicated by their name, while the more usual type of crank with rectangular webs leaves the forge in the form of a shaft with solid slabs of metal projecting at the places where the throws will eventually be. The bent crank was formerly the standard type for traction and portable engines, as well as for many of the smaller fixed engines, and as Lincoln was the great centre for the manufacture of agricultural engines, it was natural that a large proportion of the shafts made in the early days by Messrs. Clarke's Crank and Forge Company were of the bent type. A certain number of such cranks are still made for engines of the kind in question, but the type has now been to a great extent superseded by the slab crank with machined webs, as the latter is of better appearance, and with modern methods of manufacture there is no great difference in cost.

One of the difficulties of making the bent cranks for traction and portable engines was to keep the corners from becoming unduly flattened by the stretching of the metal when forced round the very sharp bends required. This was overcome by upsetting the shafts to a certain amount before bending. In the actual bending, which is performed in one heat, the shaft is rested on an anvil at the point where the crankpin is to be and gripped by the descent of the ram of a hydraulic press upon it. Two inclined rams, one on each side of the holding ram, then come down and bend the shaft downwards round the anvil and more or less into the shape required. Easily replaceable tools are fitted to these bending rams, which are changed as the work proceeds. Finally, two other rams lying horizontally in line with the crankshaft come forward and press the shaft inwards from each end, so that it fits snugly to the form of the anvil. The job is carried out more expeditiously and perfectly than one might imagine, and considerable skill is shown in obtaining the desired result.

(To be continued.)

THE EXPONENTIAL METHOD IN THE ANALYSIS OF THE BALANCE OF RECIPROCATING MASSES.

By P. Cormack, A.R.C.Sc.I.

1. It is shown in works on applied mechanics that the inertia resistance of a reciprocating piston mass is given by the rapidly convergent series:

$$F = mr\omega^2(\cos\phi + A_2\cos 2\phi + A_4\cos 4\phi + A_6\cos 6\phi + \ldots)$$

where ϕ is the angle made by the crank with the line of stroke, r the crank radius, and A_2, A_4, A_6 . . . coefficients involving the ratio of crank to connecting rod. The successive terms of the above series are referred to as the primary, the secondary, the fourth order, the sixth order . . . inertia force.

2. In works on mathematics we find for calculating $\cos\phi$ and $\sin\phi$ the convergent series:

$$\cos\phi = 1 - \frac{\phi^2}{\lfloor 2} + \frac{\phi^4}{\lfloor 4} - \frac{\phi^6}{\lfloor 6} + - \quad . \quad (1)$$

$$\sin\phi = \phi - \frac{\phi^3}{\lfloor 3} + \frac{\phi^5}{\lfloor 5} - \frac{\phi^7}{\lfloor 7} + - \quad . \quad (2)$$

Multiplying (2) by $\sqrt{-1}$, and adding to (1), we get—

$$\cos\phi + i\sin\phi = 1 - \frac{\phi^2}{\lfloor 2} + \frac{\phi^4}{\lfloor 4} + \ldots . + i\left(\phi - \frac{\phi^3}{\lfloor 3} + \frac{\phi^5}{\lfloor 5} - \ldots .\right)$$

which employing the properties of the powers of i may be written

$$1 + i\phi + \frac{(i\phi)^2}{\lfloor 2} + \frac{(i\phi)^3}{\lfloor 3} + \frac{(i\phi)^4}{\lfloor 4} + \ldots .$$

But this series is got from the exponential series by writing $i\phi$ for x in the expansion of e^x. Hence, denoting it by the symbol $e^{i\phi}$, we have

$$e^{i\phi} = \cos\phi + i\sin\phi \quad . \quad . \quad (3)$$

By multiplying (2) by i and subtracting from (1) we obtain

$$e^{-i\phi} = \cos\phi - i\sin\phi. \quad . \quad . \quad (4)$$

where $e^{-i\phi}$ is defined as the infinite series obtained by writing $-i\phi$ for x in the expansion of e^x.

From (3) and (4) we get

$$\cos\phi = \frac{1}{2}(e^{i\phi} + e^{-i\phi})$$

$$\sin\phi = \frac{1}{2i}(e^{i\phi} - e^{-i\phi})$$

Also, in consequence of (3) and (4) we have $e^{i\pi} = -1$; $e^{-i\pi} = -1$; $e^{2i\pi} = 1$; $e^{\pm 2ki\pi} = 1$

3. In a proposed engine let there be c cranks making angles θ, 2θ, 3θ, . . . $(c-1)\theta$, with crank No. 0, $c\theta$ being equal to 2π. Further, let the reciprocating mass, crank radius, and connecting rod be the same for all cylinders (or let the product of reciprocating mass and crank radius, and the ratio of crank to connecting rod be the same for all). When crank No. 0 makes an angle a with the line of stroke, the angles made by the cranks 1, 2, 3, . . . $(c-1)$ are $a+\theta$; $a+2\theta$; $a+3\theta$; . . . $a+(c-1)\theta$ respectively. In this configuration, the total inertia force of the nth order, being the sum of the nth order inertia forces of cranks at the above angles, is given by the expression:

$$F_n = mr\omega^2 A_n \left\{\cos na + \cos n(a+\theta) + \cos n(a+2\theta) + \ldots + \cos n(a+[c-1]\theta)\right\}$$

Substituting the exponential values of the circular functions this becomes

$$\frac{mr\omega^2 A_n}{2}\left\{(e^{nia} + e^{-nia}) + (e^{ni(a+\theta)} + e^{-ni(a+\theta)}) + (e^{ni(a+2\theta)} + e^{-ni(a+2\theta)}) + \ldots + (e^{ni(a+[c-1]\theta)} + e^{-ni(a+[c-1]\theta)})\right\}$$

which may be written

$$\frac{mr\omega^2 A_n}{2}\left\{e^{nia}(1 + e^{ni\theta} + e^{2ni\theta} + \ldots + e^{(c-1)ni\theta}) + e^{-nia}.e^{-ni(c-1)\theta}(1 + e^{ni\theta} + e^{2ni\theta} + \ldots + e^{(c-1)ni\theta})\right\}$$

$$= \frac{mr\omega^2 A_n}{2}\left\{(e^{nia} + e^{-nia}.e^{-ni(c-1)\theta})\left[1 + e^{ni\theta} + e^{2ni\theta} + \ldots + e^{(c-1)ni\theta}\right]\right\}$$

Since the factor in the circumflex brackets cannot be zero for all values of a, F_n will be zero only when the expression in the square brackets is zero. Denoting this quantity by E, we have

$$E = 1 + e^{ni\theta} + e^{2ni\theta} + \ldots . + e^{(c-1)ni\theta}$$

Multiplying both sides by $e^{ni\theta}$, we get

$$E.e^{ni\theta} = e^{ni\theta} + e^{2ni\theta} + e^{3ni\theta} + \ldots . + e^{cni\theta}$$

and hence by subtraction

$$E(1 - e^{ni\theta}) = 1 - e^{cni\theta} = 1 - e^{2ni\pi} = 0$$

Therefore, E is zero unless $1 - e^{ni\theta}$ be zero. But $1 - e^{ni\theta}$ is zero when $ni\theta = 2ki\pi$, that is when $n\theta$ is a multiple of 2π, or, in other words, when n is a multiple of c, since $c\theta = 2\pi$. Hence, the inertia forces of only those orders which are integral multiples of the number of cranks are unbalanced. For example, the three crank at 120 deg. six-cylinder petrol engine has the inertia forces of all orders balanced except those of the 6th, 12th, 18th, &c., orders. The two crank at 180 deg. four-cylinder petrol engine has the second, fourth, and, in fact, all higher order inertia forces unbalanced.

4. Let the cylinders of the proposed engine be spaced at distances l_0, l_1; l_2; . . . from any fixed reference plane. Taking moments about an axis in this plane we have for the inertia couple of the nth order:

$$C_n = \frac{mr\omega^2 A_n}{2}\left\{l_0(e^{nia} + e^{-nia}) + l_1(e^{ni(a+\theta)} + e^{-ni(a+\theta)}) + \ldots .\right\}$$

$$= \frac{mr\omega^2 A_n}{2}\left\{e^{nia} + e^{-nia}.e^{-ni(c-1)\theta}\right\}(l_0 + l_1 e^{ni\theta} + l_2 e^{2ni\theta} + \ldots + l_{c-1} e^{(c-1)i\theta})$$

Hence C_n is zero when the expression

$$l_0 + l_1 e^{ni\theta} + l_2 e^{2i\theta} + \ldots \text{ is zero.}$$

5. Applying these results to a seven-crank engine, we see from section 3 that the primary and secondary inertia forces are in balance. Balance of the primary couple requires

$$l_0 + l_1 e^{i\theta} + l_2 e^{2i\theta} + l_3 e^{3i\theta} + l_4 e^{4i\theta} + l_5 e^{5i\theta} + l_6 e^{6i\theta} = 0$$

Assuming the cylinders to be symmetrically placed with respect to the middle cylinder No. 3, and taking the reference plane through this cylinder, we have $l_3 = o$; $l_4 = -l_2$; $l_5 = -l_1$; $l_6 = -l_0$. Putting these values in the above expression, we get

$$l_0(1 - e^{6i\theta}) + l_1(e^{i\theta} - e^{5i\theta}) + l_2(e^{2i\theta} - e^{4i\theta}) = 0$$

$$= -e^{3i\theta}\left\{l_0(e^{3i\theta} - e^{-3i\theta}) + l_1(e^{2i\theta} - e^{-2i\theta}) + l_2(e^{i\theta} - e^{-i\theta})\right\} = 0$$

$$\therefore l_0 \sin 3\theta + l_1 \sin 2\theta + l_2 \sin\theta + 0$$

Since $\theta = 51°\cdot26'$ this becomes

$$0\cdot4336\, l_0 + 0\cdot9749\, l_1 + 0\cdot7819\, l_2 = 0.$$

By putting $l_0 = 1$ and $l_1 = 2$ we get $l_2 = -3\cdot05$

The negative sign means that cylinder No. 2 is not on the same side of the reference plane as No. 0 and No. 1. Hence, we have the interesting result that the seven cylinders arranged with the cranks in the sequence 4θ, θ, 0, 3θ, 6θ, 5θ, 2θ, and at practically equal pitches are in balance for primary and secondary forces and for primary couples.

For balance of secondary couples, we must have

$$l_0 + l_1 e^{2i\theta} + l_2 e^{4i\theta} + l_3 e^{6i\theta} + l_4 e^{8i\theta} + l_5 e^{10i\theta} + l_6 e^{12i\theta} = 0$$

which substituting $l_6 = -l_0$; $l_5 = -l_1$; $l_4 = -l_2$ $l_3 = 0$; becomes

$$l_0(1 - e^{12i\theta}) + l_1(e^{2i\theta} - e^{10i\theta}) + l_2(e^{4i\theta} - e^{8i\theta}) = 0$$

$$\therefore -e^{6i\theta}\left\{l_0(e^{6i\theta} - e^{-6i\theta}) + l_1(e^{4i\theta} - e^{-4i\theta}) + l_2(e^{2i\theta} - e^{-2i\theta})\right\} = 0$$

$$\therefore l_0 \sin 6\theta + l_1 \sin 4\theta + l_2 \sin 2\theta = 0$$

For balance of primary and secondary couples, we, therefore, require

$$l_0 \sin 3\theta + l_1 \sin 2\theta + l_2 \sin\theta = 0$$

$$l_0 \sin 6\theta + l_1 \sin 4\theta + l_2 \sin 2\theta = 0$$

Substituting numerical values and solving we find $l_1 = -1\cdot8\, l_2$ and $l_0 = 2\cdot25\, l_2$. The cylinder arrangement is, therefore, 0, 5θ, 2θ, 3θ, 4θ, θ, 6θ, and the pitches between the successive pairs are ·45, ·8, 1, 1, ·8, ·45.

6. *Desaxé Engines.*—In a desaxé or offset cylinder engine, the inertia resistance of the reciprocating parts is given by

$$F = mr\omega^2\left\{\cos\phi + B_2\cos 2\phi + B_4\cos 4\phi + \ldots . + D_1\sin\phi + D_3\sin 3\phi + D_5\sin 5\phi + \ldots .\right\}$$

where B_2, B_4, . . . D_1, D_3 . . . are coefficients involving the ratio of crank to connecting rod, and the ratio of offset to crank. The terms of the cosine series are dealt with as in the corresponding series for the symmetrical engine and the results obtained for the balance of the symmetrical engine apply to the balance of the even harmonics of the offset engine. Written in exponential form, the total inertia force of the nth order of the sine series, or the nth odd harmonic, as it is called, becomes (the engine being of the type dealt with in section 3),

$$F_n = \frac{mr\omega^2}{2i}\left\{(e^{nia} - e^{-nia}) + (e^{ni(a+\theta)} - e^{-ni(a+\theta)}) + (e^{ni(a+2\theta)} - e^{-ni(a+2\theta)})\right\}$$

$$= \frac{mr\omega^2}{2i}\left\{e^{nia} - e^{nia}.e^{-ni(c-1)\theta}\right\}(1 + e^{ni\theta} + e^{2ni\theta} + \ldots + e^{(c-1)ni\theta})$$

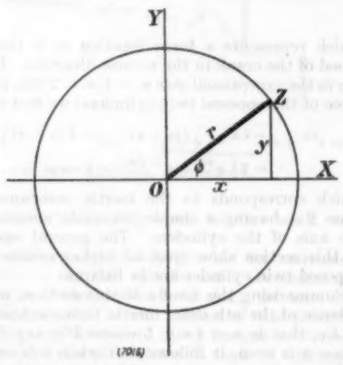
Thus, we have F_n zero when the expression in the circumflex brackets is zero. It will be remembered that this expression is zero when n is a multiple of c. Hence the odd harmonics of the nth order are in balance unless n be a multiple of the number of cranks. Plainly, an engine having an even number of cranks has no unbalanced odd harmonic—n being odd is not a multiple of c when c is even. Thus, the four cylinder desaxé petrol engine has no unbalanced odd harmonic. The six cylinder 3-crank at 120° desaxé engine has the 3, 9, 15th . . . harmonic unbalanced.

7. The results of section 6 apply to the balance of the transverse couples occasioned by the angular inertia resistance of the connecting rods of the symmetrical engine. The rod is not in general dynamically equivalent to two detached masses at the wrist and crank pins. If I be the difference in the moments of inertia of the rod and the two detached masses at the crank and wrist pins determined in the usual way ($m_1 + m_2 = M$; $m_1 l_1 = m_2 l_2$), the transverse inertia couple is given by the series

$$T = I\omega^2(C_1\sin\phi + C_3\sin 3\phi + C_5\sin 5\phi + \ldots .)$$

C_1, C_2, C_3 . . . being coefficients involving the ratio of crank to connecting rod. From section 6 we see that with an even number of cranks there is no unbalanced inertia transverse couple. The six-cylinder 3-crank at 120° has the third, ninth, fifteenth orders transverse couples unbalanced.

8. *Radial Engines.*—Expressing the inertia forces as complex quantities enables us to carry out their geometrical addition as an operation of arithmetic, even though they act in different directions. A force O Z in a direction making an angle ϕ with O X is completely represented by the complex quantity $x + iy$ or in polar co-ordinates by $r(\cos\phi + i\sin\phi)$. This, it will be remembered, may be written in the form $re^{i\phi}$. Writing $re^{i\phi} \times e^{ia} = re^{i(\phi+a)}$ shows that multiplication by e^{ia} rotates the vector O Z in the positive direction through an angle a. Again, writing $re^{i\phi} \times e^{-ia} = re^{i(\phi-a)}$ shows that multiplication by e^{-ia} rotates the vector O Z in the negative direction through an angle a. The



radial c cylinder one crank engine may be considered as derived from a c crank coincident cylinder type by rotation (without relative motion of the piston and cylinder) of crank, rod and cylinder of the second, third, fourth . . . cylinder through an angle $-\theta$, -2θ, -3θ . . . respectively whereby all the cranks are made to coincide, and the cylinders to make angles θ with each other. From this point of view, it will be evident that the (complex) expressions for the inertia forces of the cylinders 0, 1, 2, 3 . . . radial type are obtained by a rotation of the inertia forces of the ordinary type through angles 0, $-\theta$, -2θ, -3θ . . . respectively.

9. To obtain an expression for the nth order

inertia force of a c cylinder radial engine, we, therefore, write down the inertia forces for a cylinder in line type having cranks at α, $\alpha + \theta$, $\alpha + 2\theta$, ... $\alpha + (c-1)\theta$ with the line of stroke and then add after having multiplied the successive terms by 1, $e^{-i\theta}$ $e^{-2i\theta}$, . . . respectively. Leaving out the constant factor $\frac{1}{2} m r w^2 A_n$, the n'th order inertia force for a radial engine with cylinders at θ will appear as follows (the crank making an angle α with the vertical).

$$\text{Cylinder No. } 0 = \left(e^{ni\alpha} + e^{-ni\alpha}\right)$$

$$\text{Cylinder No. } 1 = \left(e^{ni(\alpha+\theta)} + e^{-ni(\alpha+\theta)}\right)e^{-i\theta}$$

$$\text{Cylinder No. } 2 = \left(e^{ni(\alpha+2\theta)} + e^{-ni(\alpha+2\theta)}\right)e^{-2i\theta}$$

" " = ...

Summing, we get

$$F_n = e^{ni\alpha}\left(1 + e^{(n-1)i\theta} + e^{(n-1)2i\theta} + \ldots\right) + e^{-ni\alpha}\left(1 + e^{-(n+1)i\theta} + e^{-(n+1)2i\theta} + \ldots\right)$$

$$= e^{ni\alpha}\left(1 + e^{(n-1)i\theta} + e^{(n-1)2i\theta} + \ldots + e^{(n-1)(c-1)i\theta}\right) + e^{-ni\alpha}.e^{-(n+1)(c-1)i\theta}\left\{1 + e^{(n+1)i\theta} + e^{(n+1)2i\theta} + \ldots + e^{(n+1)(c-1)i\theta}\right\}$$

Plainly, F_n is zero when the expressions in the brackets are both zero. Referring to the E series discussed in section 3, it is evident that the series having $n+1$ for index is zero, except when $n+1$ is an integral multiple of the number of cylinders, and the series having $n-1$ for index is zero, except when $n-1$ is an integral multiple of the number of cylinders and when $n = 1$. Hence the inertia forces of the nth order are unbalanced when $n = 1$ or when $n \pm 1$ is an integral multiple of the number of cylinders. When $n = 1$ and when $n - 1$ is a multiple of c each term of the series in the circumflex brackets in unity while the series in the chain brackets vanishes (since when $n - 1$ is a multiple of c, $n + 1$ cannot be a multiple of c except when $c = 2$ and $n = 1$ which case is dealt with separately). We therefore have

$$F_n = e^{ni\alpha}(1 + 1 + 1 + \ldots) = ce^{ni\alpha}$$

which represents a constant force whose direction swings round at n times the speed of the crank. When $n = 1$ it is possible to balance this by a suitable mass on the crankshaft opposite the crank pin. When $n + 1$ is a multiple of c, each term of the series having $n + 1$ for index is unity while the series in the circumflex brackets is zero, so that in this case we have

$$F_n = ce^{-ni\alpha}$$

which represents a force rotating at n times the speed of the crank in the reverse direction. Returning to the exceptional case $n = 1$, $c = 2$ (the primary force of the opposed twin cylinders) we find directly

$$F_1 = e^{i\alpha} + e^{-i\alpha} + \left(e^{i(\alpha+\pi)} + e^{-i(\alpha+\pi)}\right)e^{-i\pi} = 2\left(e^{i\alpha} + e^{-i\alpha}\right) = 4\cos\alpha$$

which corresponds to the inertia resistance of a mass $2m$ having a simple harmonic motion along the axis of the cylinders. The general equations of this section show that all higher orders of the opposed twin cylinder are in balance.

Summarising the results of this section, we have balance of the nth order inertia forces unless $n \pm 1 = kc$, that is $n = kc \pm 1$ where k is any integer. Since n is even, it follows that when c is even, all orders are in balance except the primary, and when c is odd, the unbalanced orders in addition to the primary are given by $kc \pm 1$ where k is any odd number. Thus, the three cylinder Brotherhood engine has the primary, secondary, 4th, 8th, 10th . . . . orders unbalanced.

In the radial engine, the transverse couples due to the angular acceleration of the connecting rods are identical with the couples due to the rods of the corresponding cylinder in line type. Expressions corresponding to those of section 4 may be readily deduced for cases in which the cylinders of a radial engine are not coplanar.

10. Applying the results of section 9 to a two-cylinder V at θ we have the nth order inertia force given by

$$F_n = e^{ni\alpha} + e^{-ni\alpha} + \left\{e^{ni(\alpha+\theta)} + e^{-ni(\alpha+\theta)}\right\}e^{-i\theta}$$

$$= e^{ni\alpha} + e^{-ni\alpha} + e^{ni\alpha}.e^{(n-1)i\theta} + e^{-ni\alpha}.e^{-(n+1)i\theta}$$

Putting $n = 1$ and $\theta = \frac{\pi}{2}$, this becomes

$$e^{i\alpha} + e^{-i\alpha} + e^{i\alpha}.e^{0} + e^{-i\alpha}.e^{-i\pi} = 2e^{i\alpha}$$

This, representing as it does, a force along the crank, may be balanced by a suitable mass on the crankshaft opposite the crankpin. Putting $n = 2$ and $\theta = \frac{\pi}{2}$ in the above expression, we get

$$F_2 = e^{2i\alpha} + e^{-2i\alpha} + e^{2i\alpha}.e^{i\frac{\pi}{2}} + e^{-2i\alpha}.e^{-3i\frac{\pi}{2}}$$

$$= e^{2i\alpha} + e^{-2i\alpha} + e^{2i\alpha}.e^{i\frac{\pi}{2}} + e^{-2i\alpha}.e^{-2\pi i}.e^{i\frac{\pi}{2}}$$

$$= \left(e^{2i\alpha} + e^{-2i\alpha}\right)\left(1 + e^{i\frac{\pi}{2}}\right) = \left(e^{2i\alpha} + e^{-2i\alpha}\right)\left(e^{i\frac{\pi}{4}} + e^{-i\frac{\pi}{4}}\right)e^{i\frac{\pi}{4}}$$

$$= 4e^{i\frac{\pi}{4}}\cos 2\alpha.\cos 45° = e^{i\frac{\pi}{4}}\sqrt{8}\cos 2\alpha$$

representing the inertia resistance of a mass having a simple harmonic motion in a direction 45° ahead of cylinder No. 0.

11. *Rotating Cylinder Engine.*—When the cylinder makes an angle ϕ with the crank (which we shall assume to be vertical) let the distance of the piston from the crankshaft centre be s. Since s makes an angle ϕ with the vertical, it is, with reference to a fixed vertical axis, completely represented by $se^{i\phi}$, which plainly is a distance s measured vertically and rotated through an angle ϕ. With reference to the fixed vertical axis, the piston velocity is, therefore:

$$\frac{d}{dt}\left(se^{i\phi}\right)$$

and the piston acceleration:

$$\frac{d^2}{dt^2}\left(se^{i\phi}\right)$$

Remembering that both s and ϕ are functions of the time, we obtain on differentiation

Piston velocity

$$\frac{d}{dt}\left(se^{i\phi}\right) = \frac{ds}{dt}.e^{i\phi} + \frac{d\phi}{dt}.si\,e^{i\phi}$$

Piston acceleration

$$\frac{d^2}{dt^2}\left(se^{i\phi}\right) = \frac{d^2s}{dt^2}.e^{i\phi} + \frac{ds}{dt}.\frac{d\phi}{dt}.ie^{i\phi} + \frac{ds}{dt}.\frac{d\phi}{dt}.ie^{i\phi} + \left(\frac{d\phi}{dt}\right)^2 s i^2 e^{i\phi} + \frac{d^2\phi}{dt^2}.si\,e^{i\phi}$$

$$= e^{i\phi}\left\{\frac{d^2s}{dt^2} + 2i\frac{d\phi}{dt}.\frac{ds}{dt} - s\left(\frac{d\phi}{dt}\right)^2 + si\frac{d^2\phi}{dt^2}\right\}$$

Writing ω for $\frac{d\phi}{dt}$, and assuming ω constant, the last term is zero, so that the expression for the piston acceleration becomes:

$$e^{i\phi}\left(\frac{d^2s}{dt^2} + 2i\omega\frac{ds}{dt} - s\omega^2\right).$$

Referring to works on applied mechanics, we find the expression for s:

$$s = r(\cos\phi + C_0 + C_2\cos 2\phi + C_4\cos 4\phi + \ldots)$$

whence on differentiation remembering $\phi = \omega t$

$$\frac{ds}{dt} = -r\omega(\sin\phi + B_2\sin 2\phi + B_4\sin 4\phi + \ldots)$$

$$\frac{d^2s}{dt^2} = -r\omega^2(\cos\phi + A_2\cos 2\phi + A_4\cos 4\phi + \ldots)$$

Setting these values in the expression for the acceleration of the rotating cylinder piston, it becomes

$$-r\omega^2 e^{i\phi}\left\{\begin{matrix} C_0 + 2\cos\phi + 2i\sin\phi + D_2\cos 2\phi \\ + D_4\cos 4\phi + \ldots \\ + i(E_2\sin 2\phi + E_4\sin 4\phi + \ldots)\end{matrix}\right\}$$

Written in exponential form the primary force for the cylinder, making an angle ϕ with the vertical becomes

$$mr\omega^2 e^{i\phi}\left\{C_0 + 2e^{i\phi}\right\} = mr\omega^2\left(C_0 e^{i\phi} + 2e^{2i\phi}\right)$$

For a c cylinder at θ with cylinders making angles ϕ, $\phi + \theta$, $\phi \times 2\theta$ . . . with the vertical, the total primary inertia force becomes (omitting the factor $mr\omega^2$):

$$C_0\left(e^{i\phi} + e^{i(\phi+\theta)} + e^{i(\phi+2\theta)} + \ldots\right) + 2\left(e^{2i\phi} + e^{2i(\phi+\theta)} + e^{2i(\phi+2\theta)} + \ldots\right)$$

$$= C_0 e^{i\phi}\left(1 + e^{i\theta} + e^{2i\theta} + \ldots + e^{(c-1)i\theta}\right) + 2e^{2i\phi}\left(1 + e^{2i\theta} + e^{4i\theta} + \ldots e^{2(c-1)i\theta}\right)$$

The series in the brackets are both zero unless (see section 3) $\theta = 2$ when neither series vanishes or $\theta = 180°$, when the second series does not vanish. Hence, in the rotating cylinder engine the primary forces are in balance for any number of cylinders greater than two.

Referring again to the expression for the acceleration of the rotating piston, it is evident that the nth order inertia force for cylinder making an angle ϕ with the vertical is:

$$mr\omega^2 e^{i\phi}\left(D_n\cos n\phi + iE_n\sin\cos\phi\right)$$

Omitting the factor $mr\omega^2$ and writing in exponential form this becomes

$$e^{i\phi}\left\{\left(D_n + E_n\right)e^{ni\phi} + \left(D_n - E_n\right)e^{-ni\phi}\right\}$$

which we may write more conveniently in the form

$$Ke^{(n+1)i\phi} + Le^{-(n-1)i\phi}$$

In a c cylinder at θ, the cylinders 0, 1, 2, . . . will make angles ϕ, $\phi + \theta$, $\phi + 2\theta$, . . . with the vertical so that the inertia forces of the nth order are

$$\text{Cyl. No. } 0 = Ke^{(n+1)i\phi} + Le^{-(n-1)i\phi}$$

$$\text{Cyl. No. } 1 = Ke^{(n+1)i(\phi+\theta)} + Le^{-(n-1)i(\phi+\theta)}$$

$$\text{Cyl. No. } 2 = Ke^{(n+1)i(\phi+2\theta)} + Le^{-(n-1)i(\phi+2\theta)}$$

Adding, we get the total inertia force of the nth order to be

$$Ke^{(n+1)i\phi}\left\{1 + e^{(n+1)i\theta} + e^{(n+1)2i\theta} + \ldots + e^{(n+1)(c-1)i\theta}\right\} + Le^{-(n-1)i\phi}.e^{-(n-1)(c-1)i\theta}\left\{1 + e^{(n-1)i\theta} + e^{(n-1)2i\theta} + \ldots + e^{(n-1)(c-1)i\theta}\right\}$$

In section 6 it was shown that the series in chain brackets are each zero unless $n + 1$ or $n - 1$ be an integer multiple of the number of cylinders. Hence, as in the radial engine, the unbalanced orders in the rotating cylinder engine are given by $n = kc \pm 1$ where k is any odd number. For example, the Gnome 5 cylinder has the 4th, 6th, 14th, 16th, &c., orders unbalanced.

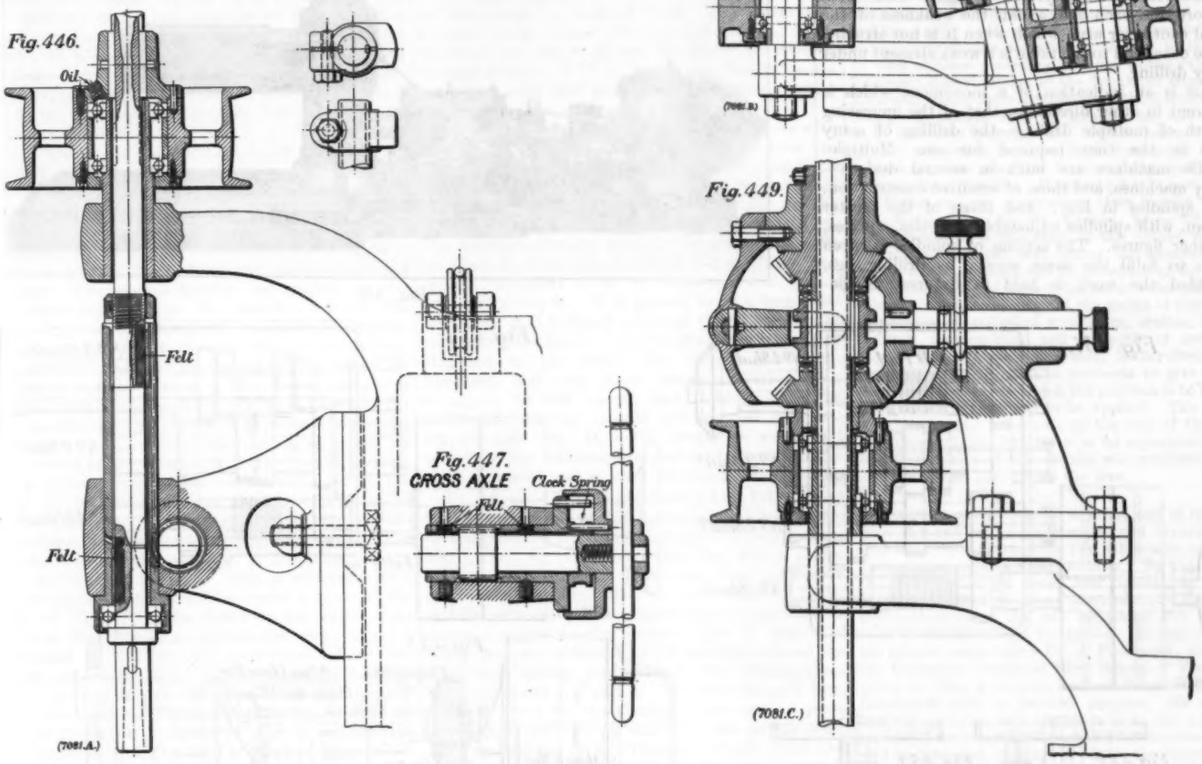
Considering the rotary engine as being derived from the radial engine by the imparting to the whole mechanism of the latter of a motion equal and opposite to that possessed by the crank, it will be at once apparent that the angular acceleration of the connecting rods are identical in the radial and rotary types (since the addition of a uniform angular velocity to a machine piece does not alter its angular acceleration). The balance of the connecting rods of the rotary engine is, therefore, determined as in section 7.

RECENT MACHINE-TOOL DEVELOPMENTS.—No. XXIII.

By JOSEPH HORNER.

SOME attention may now be given to the subject of drilling machines. If it seems a little remarkable that the designs in which these occur are very numerous and varied, it must be remembered that the drilling of holes, with reaming and allied operations is one of the largest group of performances in any machine shop. It was not always so, in the days of cored holes and black fitting bolts, employed when drilling was a very slow and costly task. Though the designs of machines have become more numerous of late years, developments have been chiefly noticeable in certain details of the fittings, and in special adaptations of machines modified for particular purposes, in order to favour mass production. A movement of another kind is an extension of the functions of single machines to enable them to perform several distinct operations on one piece of work without the necessity of moving

it about between different machines, and this has tended towards higher complication. But all machines, even the simplest, contain more of detail than their predecessors did, the elements are built up with a larger number of pieces, and provisions that make for efficiency are multiplied. The extra stresses now imposed on the drills, their greatly enhanced speeds, and the general employment of high-speed tool steel have combined to reveal the weakness and total inefficiency of the old machines, which have been of necessity re-designed on more generous proportions, as well as with a more approximate regard to the nature and severity of the stresses imposed, and the diminution of friction. Belt pulley changes, too, have largely disappeared in favour of the geared changes now common on lathes and other machines, these generally affording a more extensive range. On the other hand, direct belt drives are adopted on the lighter machines, for spindle pulleys, taking the place of gears that were always regarded as essential in the past.



FIGS. 446 TO 449. DETAILS OF HIGH-SPEED DRILLING MACHINES; MESSRS. FREDERICK POLLARD AND CO., LIMITED, LEICESTER.

The great groups of machines may be broadly classified as follows:

Bench drilling machines are a relatively unimportant group from the engineers' point of view. They are used chiefly in the small repair shops and on out-door erections. The group is a large one nevertheless, since the machines are operated either by hand, or are belt-driven, and are fed by hand or treadle, or are self-acting, and are single or double-geared. None are of large dimensions. They will drill up to about 1¼ in., and take work to about 24 in. in diameter, and 10 in. in depth. Tables are mostly plain, *i.e.*, not compound. They swivel laterally on a socket, which may also be moved along a base with bolt slots. Tables can be elevated and lowered. At the present time these machines are regarded as being very slow in operation, and the moderate range in the sizes of holes drilled is dealt with much more rapidly on the sensitive, and other high-speed machines that are belted direct to the spindle sleeve. The bench drills that are of value in the big engineers' shops are those built on the sensitive model, and belt-driven. The only difference between these and the column machines of the same class is the shortened column, and the foot made to bolt to the bench. They drill up to ½ in. diameter, and are of much utility when mounted in gangs for repetitive service.

The group of machines that are attached to walls is more powerful than the bench design, and they form a link with the radials, since the drilling arm is pivoted to move in a radius. They are hardly used in the machine shop, but are employed extensively in plating and boiler shops, and in bridge and girder works. There may or may not be a table supported from the wall, generally not, the work being carried on trestles. The common practice is, to dispose a row of machines along a wall, each operating on a section of plating, or on a framing, which is supported on trestles. They are single or double geared. The feed is by hand wheel or lever. A battery ofsuch machines will deal with work that is too long to be put on the table of an ordinary machine, and all will be operating simultaneously. These being built for special duties, are not intended to take the place of pillar, or radial arm machines. An arm pivoted to a wall cannot be so stable as a spindle mounted against a pillar. It is inconvenient to have a radial arm without the capacity for vertical adjustment. It is a disadvantage to have no table as an integral portion of the machine. But within the sphere of the duties for which they are designed, the wall machines retain the place which they have held securely for a long period.

The majority of the machines in common use belong to the pillar or column designs, which range from the very light sensitive types to those of the heaviest character. All which these possess in external aspect is the pillar, standing alone, or as a portion of a framing, the vertical spindle, and a table. They vary greatly in these details, and the range of their capacity is extensive. In the larger sizes they will drill up to 3 in., with back gears, and vertical feeds may range from 8 in. to 30 in. The spindles are counterbalanced, and often have provisions for reversing for the work of tapping. Tables occur in many forms. A plain table slides vertically on the pillar, and no adjustment of the work after it has been fixed can be made except for height. Many tables have a rotary movement. Others have a radial adjustment. Compound tables have two slides moving at right angles with each other. Tables are frequently hinged to their columns, to be turned aside to permit of bolting deep articles to the baseplate of the machine framing. Tables having a horizontal surface only, it is often necessary to use an angle plate when work should be attached to a vertical face. Many tables, therefore, are essentially angle plates, having one, or two vertical faces. Tables are elevated by means of a screw and nut, or a rack and pinion. As all these machines have spindles that possess vertical movements only, all lateral adjustments for holes at different centres have to be imparted to the work on the tables.

The radial-arm machines provide for universal movements to the drill spindle, since the radiating adjustments of the spindle head along the arm are combined with the lateral motion of the pivoted arm. The arm has also in many designs a vertical adjustment on its pillar to suit work of different depths, and some spindles can be set to drill at an angle, in a vertical plane. Some have rising and falling tables. The heavy machines are back-geared. Of late years sensitive machines—belt-driven simply—have been built in large numbers for dealing with holes up to about 1 in. in diameter. Speeds, and feeds in the heavier machines are often changed through gear boxes from a single pulley drive, instead of through the old stepped belt cones. Reversing arrangements for tapping are usually included. Spindles are counterbalanced. The machine columns are supported on baseplates, or on boxed work beds. Work tables have vertical sides slotted for holding articles there. Many tilt for angular settings of work.

Although the radial machines are numerous and very popular, they have powerful rivals in other designs that harmonise more nearly with some

present-day requirements. These relate to multiple drilling, to jig work, and to heavier cutting. Many machines are used of the girder design, modifications of the old multiple spindle machines used by boiler makers and platers. The framing includes a base carrying the work-holding table, the uprights at the ends supporting the girder or cross rail, along which the spindle heads slide, with capacities for individual adjustments for varying centres. When a number of holes have to be drilled, distributed irregularly over an area, the radial machine is convenient, since the tangential movement of the arm, and that of the saddle radially cover the whole area within the capacity of the machine. Holes can also be drilled lineally by the movement of the saddle alone, but only as a rule, singly. With the girder design of machine, movements are imparted to the table in the transverse direction, which, with those of the numerous drilling spindles cover a large area, and include many holes being pierced simultaneously. The rigid cross rail, supported at each end, avoids the weakness of the radial cantilever arm, which when it is not strutted at the outer end to the table is a weak element under heavy drilling.

This is an indication of a movement which is apparent in other directions, that of the increasing growth of multiple drilling—the drilling of many holes in the time required for one. Multiple-spindle machines are built in several designs—heavy machines, and those of sensitive construction, with spindles in line; and those of the cluster system, with spindles adjustable in circles, squares, or other figures. The setting of spindles is often made to fulfil the same service as drilling jigs, provided the work is held in fixtures. Single-spindle machines disposed in batteries take the place of those with multiple spindles, only there is the disadvantage of having to transfer the work between machines adjacent. This may be desirable when diverse operations have to be performed on a piece, though, as will be shown later, provision is made for these on some self-contained multi-spindle machines. One result is, that the single-spindle machines, used alone, without relation to others, have a constantly lessening value in the scheme of present-day manufacture. Only or chiefly are they retained for general service. Drilling practice is now divided between these older designs, modernised greatly in regard to the details of their construction, with increased efficiency, and supplemented by the free employment of fixtures and jigs; and the later highly specialised machines, which are either designed for dealing with a larger

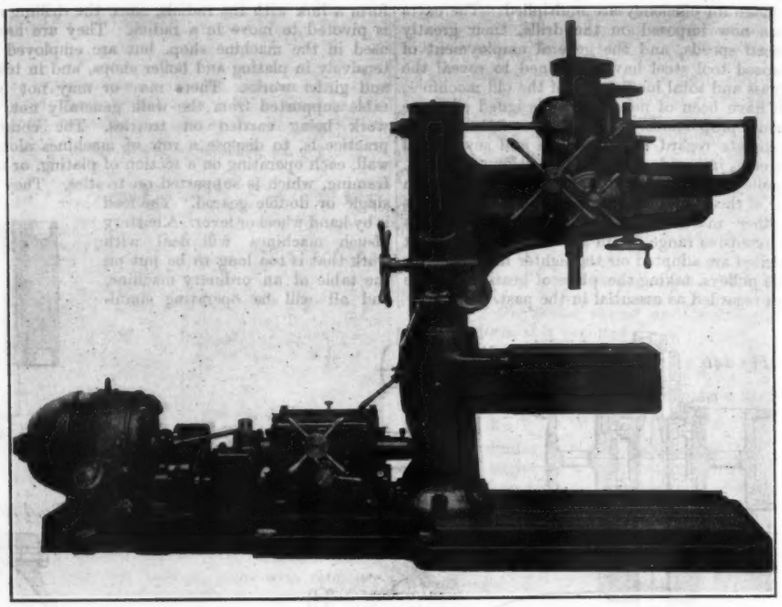
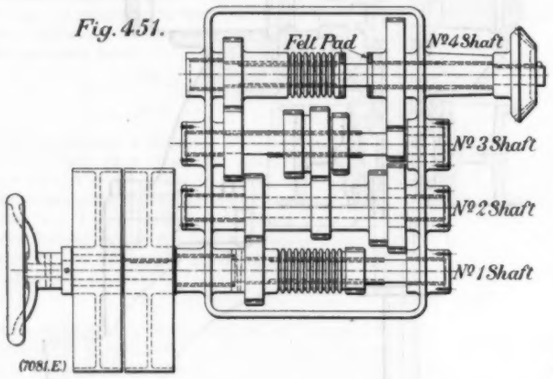
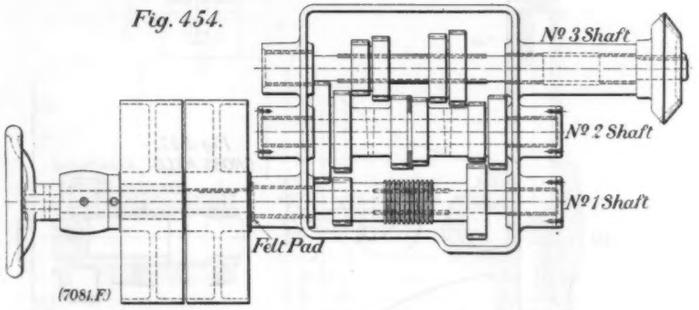
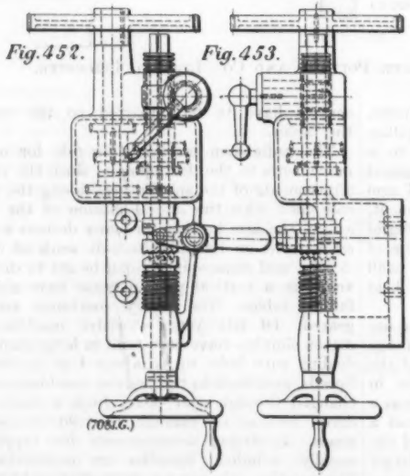
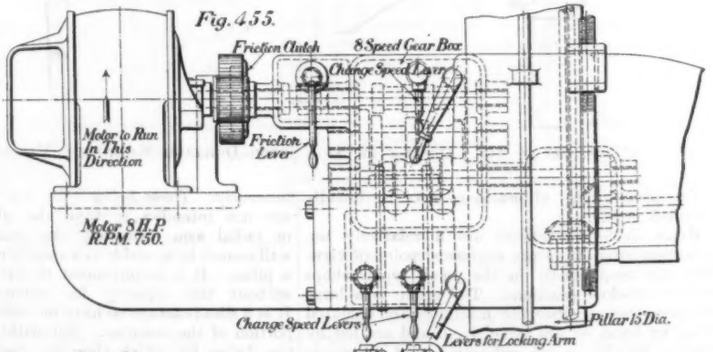


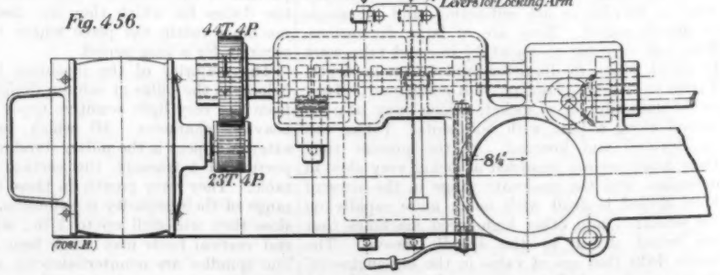
Fig. 450.











Figs. 450 to 456. 3-Ft. 6-In. Radial Drilling and Tapping Machine; Messrs. George Swift and Sons, Ltd., Halifax.

and repetitive product, yet adaptable for diverse classes of work, or which are absolutely specialised around one particular piece of work, and are not available for any other. The latter increase in numbers, chiefly in connection with the manufacture of motor vehicles, for which both the gang and the cluster systems of spindles are adapted. And since holes have to be drilled to different sizes and depths, and reamered, or tapped, and from faces at different angles, the spindles are permanently disposed accordingly, and all are in simultaneous action, or they operate in quick succession. Some selected examples will serve to illustrate the developments that have been evolved in recent machines.

The Figs. 446 to 449, on page 782, show some details as fitted to the high-speed drilling machines by Messrs. Frederick Pollard and Co., Limited, of the Corona Works, Leicester. The only resemblance which these bear to prototypes of a few years since is that the belt drive, taken over tension guide pulleys is retained. It has been proved that by the substitution of ball bearings on some of these machines, holes can be drilled 50 per cent. faster than with plain bearings. The latter are retained if desired, but the machines are not so efficient. With ball bearings, the sensitive machines, drilling to $\frac{1}{16}$ in., will pierce a $\frac{3}{4}$-in. hole, 1 in. deep in cast-iron in 4 seconds.

Fig. 446 shows the standard spindle used on the sensitive pillar and bench machines, with the sliding bracket for adjusting the spindle vertically. Fig. 447 shows the details of the cross axle; and Fig. 448 jockey pulleys as used on multi-spindle machines.

The spindle, Fig. 446, has two splines on opposite sides to give an equal drive and maintain perfect balance. The double-flanged belt pulley at the top does not pull on the spindle, but on the encircling sleeve, through the radial ball bearings, which are lubricated through the oil hole above. The vertical pressure of the spindle is taken on a thrust bearing below. The lower sleeve is bushed at each end, and is lubricated through the felt packings. The spindle is adjustable vertically by means of the sliding head which is locked by the central bolt. It is fed with the handle, actuating a pinion, that meshes with a rack, cut in the steel sleeve. Graduations show the amount of feed. The feed lever is adjustable, and is self-tightening with a coiled spring, Fig. 447. The spindle is balanced to prevent it dropping when a drill is breaking through. This is effected with a flat coiled clock spring that occupies a space at the right of Fig. 447. The detail at the upper right hand of Fig. 446 is an adjustable stop, that is tightened on the spindle somewhere above the pulley, to set the depth of holes in repetitive drilling. In Fig. 446 the clamping of the sliding head is shown. A hexagon-head bolt sliding in the Tee-slot of the head is tightened with a ball handle. The pulley seen at the head of the framing receives the cord for the weight that counterbalances the table.

The jockey pulleys mounted on their tension bracket, as used for some of the multiple spindle machines are shown by Fig. 448. The double guide pulleys to the right are fitted on those machines which have a two-stepped belt pulley at the top of the drilling spindle. When the belt has to be changed from the lower to the upper step of the belt cone pulley, it is placed over the top jockey, and *vice versa*. The return-belt pulley is made wide enough to permit the belt to be moved to either of the others, as indicated by the centre lines for the two positions. The multiple spindle machines just named have four spindle speeds. In the 13-in. machine—equivalent to the maximum diameter that can be admitted on the table, the spindle for which is shown in Fig. 446, the speeds with ball bearings are 408 r.p.m., 681 r.p.m., and 1,135 r.p.m. If plain bearings are fitted they are 286 r.p.m., 477 r.p.m. and 795 r.p.m. The diameter of the spindle is $\frac{7}{8}$ in. It has a vertical adjustment of 5 in., and that of the sliding head is 8 in. The multiples are built with either 1, 2, 3, 4 or 6 spindles. Each spindle has its own independent speeds, a fact which is of much value when performing repetitive work.

A feature of some of the "Corona" machines is the reverse motion, Fig. 449, for tapping. The belt pulley is seen below, similar to that in Fig. 446. The reverse to the spindle goes through the nest of clutched gears above. This is a better design than a separate tapping arrangement, which imposes a load on the spindle nose. The reversing clutch is operated with the lever seen. The reverse can be disengaged by pulling the crown bevel out of mesh with the stem at the right hand, and locking it with the pin above, entering the inner one of the two annular grooves turned in the stem.

The succeeding Figures show some of the details of the geared speed and feed boxes fitted to a 3 ft. 6 in. radial drilling and tapping machine by Messrs. George Swift and Sons, Limited, of Halifax. One of these machines, motor-driven, is seen in the view, Fig. 450, page 782. It is of that design in which the column is mounted on a low baseplate, and has a table fitting on the column, which can be swung aside when deep pieces of work have to be set on the base. The table can be locked with a handle in any lateral position. Articles can be bolted on its horizontal, or vertical faces. The radial arm swings on the upper part of the column, 7 in. diameter, on which it can be raised or lowered through a space of 10 in. with a star handle, worm gear, and rack and pinion, and be locked with a lever.

The spindle saddle is traversed along the arm with a pinion and rack. The radius measured from the centre of the pillar to the centre of the spindle is 3 ft. 6 in., the minimum is 12 in. The maximum distance from the top of the swing table to the spindle nose is 1 ft. 11 in., the minimum is 3 in. The maximum height from the base to the spindle nose is 4 ft. 3 in., the minimum is 2 ft. 7 in. The spindle measures 2 in. in diameter, and has a traverse of $10\frac{1}{2}$ in. It is ground to fit a long cast-iron bush, and is fitted with ball thrust washers at each end of the bush. The steel feed rack is securely attached to the bush. The spindle is spring-balanced, and has eight speeds, ranging from 44 r.p.m. to 489 r.p.m., and three feeds. The revolutions of the spindle per inch of feed are 80, 125 and 185. It is fed through a worm and wheel for fine adjustments, and with a star handle on a rack and pinion shaft for quick adjustments.

The 12-speed gear-box shown in Fig. 451 is fitted to the smaller sizes of drilling machines. It is shown as being driven by a constant speed pulley making 400 r.p.m. In the photograph, Fig. 450, a motor drive is substituted. There are four numbered shafts shown on Fig. 451—No. 1 is the pulley shaft, and No. 4 is that which transmits the change speeds through mitres to the spindle. The 12 speeds of No. 4 shaft are obtained by the combinations of the fixed and sliding gears shown, the sliding gears being on shafts 1, 3 and 4. Two are obtained from shaft 1, three by the sliding of the nest of gears on shaft 3, and two on shaft 4. The sliding gears have two splines each. They are of mild steel, and case-hardened. The operating levers are numbered, and no conflicting gears can be engaged.

The three-speed feed-box, Figs. 452 and 453, takes its drive from the large wheel seen at the top, which gears with a pinion on the spindle (not shown). It drives through the box to the worm which gears with the worm wheel on the spindle rack pinion shaft. The changes are effected by the three sliding gears, and are controlled by an indexed dial seen in the photograph, Fig. 450, which shows at a glance the rate of feed being used.

Fig. 454 shows the speed-box used on drilling machines from 5 ft. to 7 ft. radius. It gives eight changes obtained by sliding the gears on shafts 1 and 3. These are moved with levers that have numbered positions to correspond with numbers on a brass plate chart that is fitted on the machine. Interlocking is so done that conflicting speeds cannot be engaged. In the machines to which these speed-boxes are fitted there is double gear on the saddle, giving 16 spindle speeds, which are in geometrical progression. They range from 19 r.p.m. to 390 r.p.m. The feed-box gives six rates, obtained by the movements of levers which are indexed. The rate of feed can be read on a brass plate, fitted to the feed-box.

A group of central thrust radial machines by this firm has the arm mounted to swivel round on the column, and extended at the rear to receive the gear-box and motor, a design which enables the machine to deal with work anywhere within the full circle covered by the spindle. The gear-box for these machines is shown by Figs. 455 and 456, being cast on the arm which is carried by the column. There are 16 spindle speeds, ranging from 19 r.p.m. to 390 r.p.m., as in the previous figure—the gear arrangements being alike. A friction clutch shown, is fitted between the motor and gear-box, which permits of gears being slowed down while speed changes are being made.

NOTES ON NEW BOOKS.

THE study of statics does not particularly appeal to the average student of engineering. He is content when he is able to apply the chief considerations and formulæ he has noted down to the special cases he has to deal with; but he feels lost if the cases should lie a little outside the routine work, because he has not grasped the principles of the science. He is, moreover, rightly under the impression that nobody should accept a formula without trying to fathom it, and that the many assumptions underlying estimates of wind pressure and the traffic load on a bridge, &c., are mostly too uncertain to ensure scientific reliability in the result. In view of these considerations one would expect that Professor Robert Otzen, of the Technical High School, Hanover, would have extended the third edition of his Study of Statics into a treatise on the subject, as he had been urged to do. But he has not acceded to this suggestion because he is convinced that the subject requires adequate lecture study, and the title of his volume remains "*Praktische Winke zum Studium der Statik und zur Anwendung ihrer Gesetze*" [Berlin and Wiesbaden: G. W. Kreidel, price 20 marks]. Nevertheless he is following, in this octavo volume of 178 pages, with 125 text figures, the general method in which the problems will be presented to the student. At the beginning of each of his sections he refers to the volume, chapter and page of the works of five German authorities on technical mechanics, statics, elasticity building construction, and strength of materials—Föppl, Keck-Hotopp, Mehrtens, Müller-Breslau, and Otzen-Barkhausen—and he proceeds to give practical hints as to the way in which the problem is to be understood and the rules are to be applied. The 22 pages of bibliographic references at the end of the volume are commendable, but there is no alphabetical index. The first edition of this volume was published in 1910, and the second just before the war.

The problems of benzine as a fuel and of lubrication each demand so comprehensive and separate study that the combination of the two subjects in one volume may at first sight appear peculiar. To the oil miner and the distiller of shales and lignite the problems present themselves simultaneously, however, and representatives of the two industries will appeal to their technical colleges for advice. In this connection the subject came before Dr. J. Formanek, professor at the Bohemian Technical High School of Prague, who wrote in 1918 a German book on Benzine and Mineral Lubricants with a twofold purpose. He wished to instruct motorists and engineers as to the nature and testing of these materials and their estimation and uses, and he intended, further, to advise the chemist in this special work. The book was published in Berlin. An enlarged revised edition has since been brought out. This has been translated by Mr. Charles Salter, and is published by Messrs. Scott, Greenwood and Son (8, Broadway, Ludgate Circus, price 15*s.* net) under the title, "*Benzine and Mineral Lubricants, their Production, Testing and Uses.*" Apart from the general section the chief parts of the octavo volume of 256 pages deal with the Testing of Benzine and Benzol, and with Judging the Quality of Benzine and Benzol; similarly two sections deal with Mineral Lubricating Oils, and there are some further sections on Properties and Uses of Fuel, their Consumption and Efficiency and Storage, and a few suggestions on protecting the carburettor from cooling, on cooling the engine, and on filtering the intake air. That the term "benzol" is to signify the aromatic hydrocarbon C_6H_6, generally styled benzene in this country, should have been stated more definitely from the first. Dr. Formanek is a well-known expert; he had the assistance of engineers and refiners in his compilation, and he acknowledges in particular help given by Mr. H. Bauer, manager of the Kolin oil refineries. The book is instructive, especially as to Continental practice, though it does not, of course, embody the very important researches on lubrication recently conducted in this country.

The birth and development of the British Mercantile Marine and the eventual prosperity of its trade forms an interesting story, and it is a pity that it has not had a greater prominence in the popular histories of this

country. How many otherwise well-educated men and women there are to whom the names of the great pioneers of the mercantile marine are known—the names of such men as Master Philpot, the courageous and public-spirited merchant prince of Richard the Second's reign; William Canynge, the Bristol trader, who played so great a part in mercantile enterprises in the reign of Henry the Sixth; and Sir Henry Middleton, knighted for the fine work he did for the East India Company. The early histories of the great trading and shipping companies—the East India Company, the Cunard, the P. and O., the Castle, the Royal Mail, the Allan, and the many others—are not nearly so well known or so widely appreciated as they should be. Many will therefore welcome Mr. Archibald Hurd's book "*The Sea Traders*," published by Messrs. Cassell and Co., Limited, of London, and New York, at 7*s.* 6*d.* net. It should be read by all interested in our merchant navy. Commencing with the coming of the Romans and the battle fought by that heroic queen, Boadicea, the book traces through the many difficult periods of the succeeding centuries, the rise and progress of the British mercantile marine and of the great companies which sprang up in its wake. The second and three succeeding chapters give an account of the beginning of our overseas trade, and deal with the discoveries of the various parts of the North and South Americas by the two Cabots, Columbus and others, and of the parts these discoveries played in the increase of this overseas trade. The next eras to come under Mr. Hurd's fascinating survey is the Elizabethian period, with the formation of the East India Company and its early history. The next chapters tell of Colston of Bristol, Paterson of Dumfries, some early north country merchants, and the great merchant princes of the Georgian era; Chapter XII tells of Samuel Cunard and of the great shipping company which bears his name. The next chapter is devoted to our Atlantic shipping during the last few decades, and with the formation of the White Star Line. Then comes a chapter on the P. and O., and another on Donald Currie and the South African trade. Of the final chapters, one deals with Edward Lloyd and the two great institutions whose foundations he laid. The book has a good working index, but no illustrations.

Patternmaking is one of the most skilled of all the arts which go to make up the total of engineering practice, and it is one which every designer must have some knowledge of if he is to avoid the costly and inefficient castings which mar so many otherwise good designs. The fact that practically anything can be moulded and cast, given sufficiently good craftsmen in the pattern shop and the foundry, has its unfortunate aspect, for it enables designs to get through which cost in manufacture many times what they should. Modifications which seem almost trivial, and which are a matter of indifference to the designer, often enable a casting to be made at a fraction of the cost which would be necessary without them, and a good designer will instinctively avoid the necessity of useless and difficult work in the shops. "*Patternmaking*," by W. Roland Needham (Blackie and Son, Limited, London, 1921, price 2*s.* 6*d.* net) is an unpretentious and elementary, but really excellent little book on the practical work of the patternmaker. It is written by someone who really knows what he writes about, a compliment which one can all too rarely pay to books written on the constructive arts as distinguished from the sciences. It can therefore be confidently recommended, not only to youths in a pattern-shop, but to any apprentice or student of mechanical engineering, and indeed particularly to those whose pattern-shop experience is inadequate.

FLOATING CRANE FOR COALING VESSELS.

A new floating crane for coaling vessels, which is unique in Canada, and an advance on the few of its kind in United States ports, has recently been installed in Montreal Harbour by the George Hall Coal Company of Canada, Limited. Its features include a goose-neck boom which enables it to deliver coal into deck shoots on either side of a steamer without moving its station, and a mast of steeple construction near the top of which is located the operator's cab, giving him a clear view of his work. Another point is the unusually wide slewing angle of the boom, namely, 180 deg., enabling it to coal not only from its own stock, but from coal barges alongside. It is this feature which differentiates it from similar American plants, the plan being that it shall not carry bunker coal itself, but shall handle coal from barges that can be replaced as fast as emptied. It is claimed that this will mean an important economy, since the costly bunkering machinery can be kept in continuous operation without having to return to load itself up with coal.

As will be seen from the photograph, Fig. 1, annexed, and the drawings reproduced in Figs. 2 to 5, on page 792, the plant consists of a steeple construction of steel girders whose four legs are based across the stern of a scow. The boom, of angle and plate construction, rests on the step on the turntable, to which it is braced by two struts. Sixty-two feet from its base comes the goose-neck, set at an angle of 41 deg. the goose-neck itself being 26 ft. long, which enables the boom to reach out across a steamer's deck. This boom is so lofty that on many freight steamers the grab can be operated over the steamers' funnels. The height of lift is 70 ft. above the scow deck, or 80 ft. above water-level, and the radius of boom, with a full grab, is 60 ft. The capacity of the plant is upwards of 150 tons an hour; with a two-yard 1½-ton grab which can, it is believed, be replaced by a 2-ton grab, to increase the loading speed.

The high loading speed is attained by a twin drum hoisting engine, with central gears. The slewing engine also is of interesting design, being compound-geared, with spur gearing at one end of the drum and internal planet gearing in the other end. It is controlled by a throttle valve, and the reversing gear is operated from the cab aloft by latches which control the tumblers through an oil cylinder. This oil cylinder control permits an easy reversal to be effected, and avoids any noticeable jerk on starting.

One vertical boiler, 54 in. by 109 in., supplies steam to the bilge pump and to the three operating engines. Its working pressure is 125 lb., but pressure to the slewing engine is reduced to 50 lb. through a reducing valve. The engines are 75 h.p. for hoisting, and 40 h.p. for slewing and for raising the boom.

The scow is 110 ft. long by 35 ft. beam, not self-propelled. The engines and boiler are all carried on deck, as this particular scow was not designed for this duty, but on the next to be built it is intended to instal all plant below deck. No ballast is carried, the scow being so well proportioned that her level varies only from 1 deg. to 1½ deg. when at work.

Although designed particularly for bunkering, the crane is anticipated to be used also for wrecking work, its unusual power and proportions adapting it for that duty in an exceptional degree. With its 180 deg. of swing, the crane can load into lighters, or on to its own deck, where 500 tons of coal can be carried it desired.

The plant is also unique in being the first constructed in Canada. It was designed by the Canadian Meade-Morrison Company, Limited, who also built the engines, control gear and boiler, at their Welland Works. The hull was built by the Dominion Bridge Company, Montreal, who also carried out the structural steel work of the plant.

The special value of bunkering plant of the kind illustrated is claimed to be its ability to load deck shoots at high speed, leaving side bunkers, which always require trimming, to be loaded by a separate and smaller plant with the usual short derrick and hoist. At a short-season port such as Montreal this feature is considered to be important, as it considerably cuts down the bunkering time of steamers.

FLOATING CRANE FOR COALING VESSELS.

THE CANADIAN MEADE-MORRISON COMPANY, LIMITED, ENGINEERS.

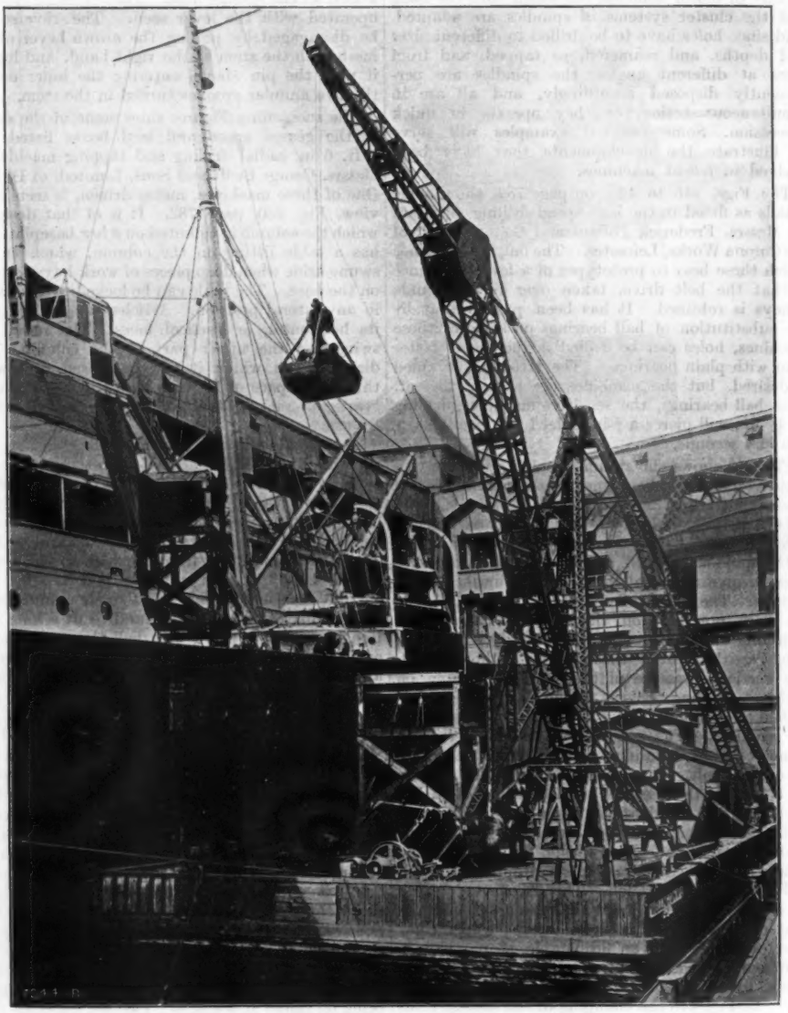
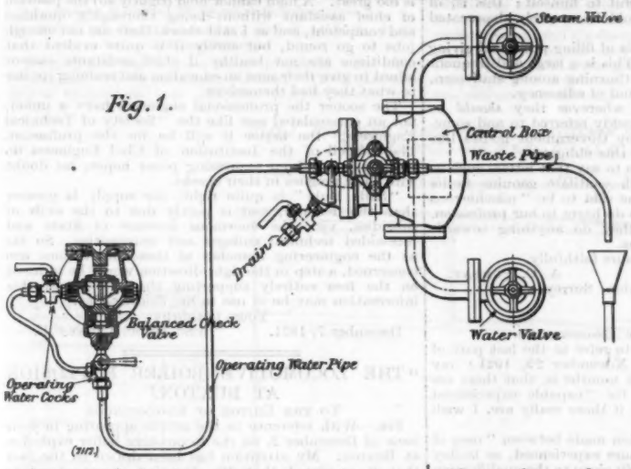
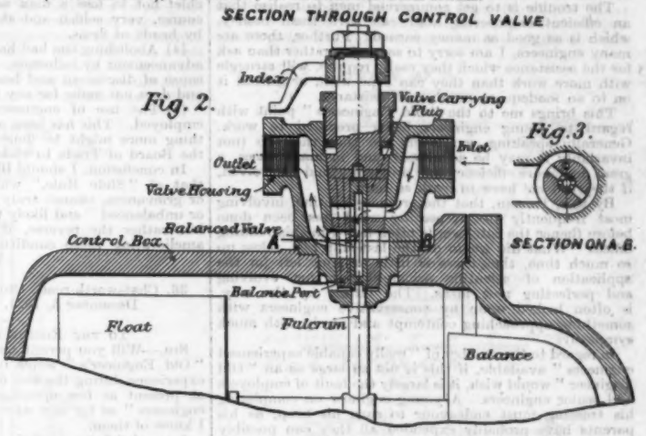


Fig. 1.

FEED-WATER REGULATOR FOR BOILERS.

CONSTRUCTED BY MESSRS. ROBERT WARNER AND CO. (ENGINEERS), LIMITED, WALTON-ON-THE-NAZE.





AUTOMATIC feed-water regulators are now in common use in connection with steam boiler plants, as the advantages of maintaining a constant water level in the boilers independently of the attention of the men in charge have become generally recognised. Figs. 1 to 3 above illustrat the type manufactured by Messrs. Robert Warner and Co. (Engineers), Limited, of Walton-on-the-Naze, Essex. The apparatus in question can readily be fitted to any existing boiler, as all parts are external to the boiler. The principle on which it acts is the control of the check valve which admits water to the boiler, by means of a float actuated by the water level in the boiler. The control is not mechanical, but hydraulic, a small pipe being the only connection between the check valve and the float box.

The check valve is provided with a balance piston cast integrally with it. The feed water coming from the pumps is delivered to the space between the underside of the check valve and the top of the balance piston. The underside of the balance piston is connected by an external pipe with the space above the piston, so that the pressure of the water on the piston is normally balanced. The check valve will then act in the ordinary way and admit water to the boiler. Should, however, the water below the piston be permitted to leak away, the piston is unbalanced and the check valve is held closed by the water pressure on top of the piston.

From the above remarks it will be seen that in the Warner regulator it is only necessary to control the small quantity of water which is bye-passed to the underside of the balance piston in order to obtain complete hydraulic control of the check valve, and therefore complete control of the feed water entering the boiler. In actual installations this quantity has been found to be less than 1 per cent. of the total water fed to the boiler. The space below the balance piston is connected by means of a pipe to the control valve situated on the side of the control box. The control box is connected to the boiler in any convenient manner which permits of the water levels in the boiler and control box being identical. The control box, shown in section in Fig. 2, contains a displacement float which rises and falls with the water level in the boiler. As the water level in the boiler rises, the float rises and opens the control valve, thus allowing the water under the balance piston to escape. Consequently, the check valve closes. Conversely, as the water level falls, the float also falls, closiug the control valve, thus preventing the escape of the water from the underside of the balance piston. The piston being then bdlanced, the pressure exerted by the feed pump will raise the check valve, and water will enter the boiler in the usual manner.

Suitable levelling valves are provided with the control box, and by shutting these valves the whole of the working parts may be taken out and examined whilst under steam and without stopping the feed. Provision is also made for varying the water level above or below the normal working level.

PLASTIC WOOD.

OUR attention has been drawn to a material which promises to answer satisfactorily a large number of very useful purposes. This material is produced by Messrs. Necol Industrial Collodions, Limited, of 62, London Wall, E.C. 2, and is named by the firm "Plastic Wood." It is a collodion preparation made with very fine wood meal, and as supplied ready for use is of the consistency of soft putty, and of much the colour of deal.

From the engineer's point of view this material will probably be of most interest in connection with pattern-making and moulding. It can be used for all ordinary filling and stopping work in wood patterns, and is exceedingly tenacious, adhering firmly to woods of all classes. It can be employed for fillets, being very quickly applied and smoothed down by the thumb or a tool. It can itself be built up into patterns if necessary, and being waterproof can be drawn from the sand without difficulty, and does not warp or deteriorate from being damped. It sets quite hard, and can be cut with an ordinary tool like wood, or turned in the lathe. For odd castings the expense of a pattern can often be saved by using the old part and building up on it where necessary a thin coat of plastic wood to make good for shrinkage and to provide machining allowance. The material adheres satisfactorily to brasses and other metals, so that castings can be made off small valves, &c., without difficulty.

It can be finished with sandpaper in the ordinary way to give a very smooth surface, and can be applied to wood backing, when it can be polished, stained and given a very highly glazed finish of a very attractive character. It is subject to slight shrinkage in drying, but we believe to a less extent than putty, and will withstand moderate heat without damage. It hardens fairly quickly when exposed to the air, but drying should not be accelerated by exposure to flame or the direct heat of a fire, owing to the vapour given off in the process. Owing to shrinkage it is sometimes desirable to build up the material in a series of layers, allowing each to harden off before applying the next. If this be done the layers will be found to adhere so firmly to each other as to be practically indistinguishable. We may add that the hardened material is not brittle, and nails can be driven firmly into it without cracking it. As the adhesive qualities of Plastic Wood are so marked, a solvent is supplied by Messrs. Necol Industrial Collodions, Limited, to enable it to be cleaned off the hands, &c., after use. This same preparation may be employed to soften Plastic Wood which may have become hardened in the tin.

A REMARKABLE ASTRONOMICAL WATCH.

AN astronomical watch which combines a very unusual number of indications has recently been completed by Messrs. S. Smith and Son, Limited, of 6, Grand Hotel Buildings, Trafalgar-square, W.C.2. The front main dial of the watch, on which ordinary time is indicated, carries four small dials. One of these shows the days of the week and the date of the month, while another shows a perpetual calendar indicating first, second, third and leap years. The third small dial indicates the phases of the moon, and in conjunction with this dial there is an indicator and pointer which shows at any time to what extent the watch is wound up. The fourth small dial acts as a recording chronograph and shows the hours and minutes, seconds and fifths of seconds being recorded by a pointer operating over a dial engraved round the outer circumference of the main dial in the way that will be generally familiar. A stop arrangement operates in connection with this chronograph mechanism, and both the second hand and the hour and minute hands of the main dial may be returned to zero at any time.

The main dial also carries a further hand which is rendered distinctive by a small sun near its outer end. This hand shows the equation of time, or the position of the sun before or after clock time. The sun and the clock agree on December 25. On December 27 the sun is 59 seconds slow as compared with clock time, while on December 28 it is 1 min. 0·29 sec. slow. By April 16 it agrees again, and on April 17 is 19 sec. fast, and so on. Sun time and clock time agree on December 25, April 16, June 14 and August 31. The coincidences vary slightly in different years. These variations are allowed for by the watch itself, as also are the variations in the number of days in the month and the special February variation in leap year. The watch strikes hours and quarters, and repeats hours, quarters and minutes at any time at will.

On the back of the watch there is a dial showing the sidereal day of 24 hours. This is the time that elapses between two successive upper culminations of a fixed star. It is shorter then a mean solar day by 3 min. 55·91 sec., so that the sidereal hour hand actually takes 23 hr. 56 min. 4·09 sec. to travel round the dial. The back of the watch also carries a star chart or planisphere. The point on the chart corresponding to the North Pole is set at the centre of the sidereal hands, and the exposed portion of the chart corresponds with the portion of the sky visible in the latitude at which the watch is used. Arrangements are made to set the chart to fulfil this condition. The chart is geared to the sidereal time movement, and the times of the rising and setting of the stars are duly indicated. The chart is of assistance in obtaining the bearing of compass points. The movements of the watch are built in three galleries or tiers, and are fitted throughout with diamond and ruby jewels. A 60-sec. revolving escapement is used which reduces the positional error to a minimum. The watch runs for 30 hours with one winding. It has an 18-carat gold case, and is certainly a very remarkable example of the watchmaker's art. We understand it was constructed to order and cost 1,000 guineas.

"ENGINEERING AS A PROFESSION."

TO THE EDITOR OF ENGINEERING.

SIR,—I should be glad of an opportunity of replying to some of the remarks of an "Old Engineer" in his letter contributed to the above correspondence. He apparently considers that there is quite insufficient room in this country for the young engineers who finish their training every year and that large numbers should be prepared to leave their country, after their parents have expended a large sum on their training.

It is strange that this should necessarily be so in a profession which has been largely responsible for the pre-eminence of this country among the nations, when the other professions such as Law, Medicine, Literature and Art, appear to involve no such necessity.

I think the fact is that the utilisation of engineers in this country is only a percentage of what it should be. All the time that we read of boiler explosions and other accidents due to incompetent men being placed in charge of machinery; of huge quantities of fuel being wasted for want of scientific methods being used; and when one knows from experience that even where there are competent chief engineers or engineers-in-charge, they cannot attend to such important matters properly because in very many cases they are not allowed an adequate staff; it can readily be realised that the country has by no means reached the saturation point with regard to the employment of engineers.

No, Sir, I venture to say that if an engineer were

employed wherever such *should* be employed, that there would be rather a shortage of engineers, especially in view of the fact that for four or five years, the number of trained men turned out was negligible.

The trouble is to get commercial men to realise that an efficient engineering staff can save them money, which is as good as money earned. Further, there are many engineers, I am sorry to say, who, rather than ask for the assistance which they really require, will struggle with more work than they can cope with, or unload it on to an inadequate number of assistants.

This brings me to the "Old Engineer's" point with regard to young engineers being prepared to work. Generally speaking, employers see that they do (not invariably it may be admitted), and in many cases, a great deal more efficiency and progress would be evolved, if they did *not* have to work so hard.

By this, I mean, that the ordinary routine, involving most frequently just repeating what has been done before (hence the catchwords often heard in shipbuilding offices "What did we do on the last ship?"), takes up so much time, that there is little or none left for the application of scientific principles, or for evolving and perfecting new ideas. The latter, by the way, is often looked upon by conservative engineers with something approaching contempt and rarely with much sympathy.

In regard to the number of "really capable experienced engineers" available, if this is not so large as an "Old Engineer" would wish, it is largely the fault of employers and senior engineers. A young engineer on completing his training must endeavour to earn his keep, as his parents have probably expended all they can possibly afford upon him. With little to guide him, he takes probably the first job that offers, suitable or unsuitable as he may find it later to be.

Having failed to get any more salary here, or having other reasons for leaving, he takes the next post with a slightly increased salary, but probably in quite a different branch of engineering, and so it goes on, the man going from one firm to another, not so much with the idea of consolidating his engineering knowledge or widening his experience, as to earn his daily bread, with some prospect of being in a position to marry.

It is obvious that such a course, which I suppose is taken in more cases than not, does not produce men highly experienced in any one branch, though it may turn out men who, knowing a little of a good many subjects, are useful to some classes of employers.

Regarding the remark that employers "shove on" capable men and "rapidly increase their salaries," I am afraid this is very much the exception, rather than the rule. Too often the remuneration is governed by the employer's knowledge (or imagination) that a man can be replaced at once by another at the same or a lower remuneration, and not by a recognition and appreciation of the man's work and length of service.

While it may be admitted that young men who are just commencing their careers and are fortunate enough to get anything at all at the present time, may be getting a remuneration (taking the cost of living into account) somewhat in advance of what was the case before the war (when, in my opinion, young men were exploited on the pretext of obtaining "experience," no allowance being made for the money value of the enthusiasm and fresh ideas that every young man brings to his first post), it still cannot be justified that a post for a research worker, requiring University and other qualification of a high type (as it should) should carry such a low salary as 350*l.* per annum. If our much vaunted research work is to be of any use, it must be adequately paid for. In connection with this question of remuneration, I should like to mention two opposite cases which have recently come under my notice. In one case, in London, a man was advertised for to revive a failing cause, and for this a salary was offered substantially less than the sum mentioned above for the research worker, and this not because more could not be afforded, as the failing cause had been taken over by a flourishing concern. The other case was that of an American firm, anxious to erect a plant in England (work occupying about a year) in a reasonably quick time.

The American engineer in charge was paid what we should consider an enormous salary, the English clerk-of-works and others engaged by him, were paid on a similar lavish scale, being given to understand, of course, that they must put their hearts into the work, and as a consequence the work went ahead very quickly and all were keen, satisfied and happy.

The fact is we don't realise the possibility of recovering money wisely expended by increased efficiency, neither is that faculty of inducing enthusiasm in others common amongst our employers and senior engineers, largely owing, I think, to a lack of sympathy for and trust in their subordinates.

As a few suggestions for improving the state of affairs touched upon above, I venture to put forward the following:—

(1) The payment of an adequate salary to young engineers from the start, so that they can have money to spare for books, &c., can start saving a little, and be a little more independent in selecting firms, where they can improve their engineering knowledge in the right direction.

(2) The encouragement by senior engineers of the continued education and advancement of those under them. They have many opportunities of seeing that their assistants understand and use scientific principles and really understand the machinery and apparatus under their care, can often give them opportunities of testing machines, visiting firms and works, and in other ways adding to their knowledge and can encourage any original ideas manifested by them, or any suggestions for increased efficiency in office, &c.

(3) Greater opportunities of advancement in the firm. In very many cases vacancies are filled from outside, which could as readily be filled from within. Sometimes this is due to the wish of some departmental chief not to lose a man useful to himself; this is, of course, very selfish and should be severely deprecated by heads of firms.

(4) Abolishing the bad habit of filling posts and giving advancement by influence. This is a large and frequent cause of discontent and heartburning among staff men, and does not make for any kind of efficiency.

(5) The use of engineers wherever they *should* be employed. This has been already referred to and something more might be done by Government bodies like the Board of Trade to make this obligatory.

In conclusion, I should like to say that letters such as that of "Slide Rule," which ventilate genuine faults or grievances, cannot truly be said to be "mischievous or unbalanced" and likely to do harm to our profession, but rather the reverse, if they do anything towards ameliorating these conditions.

Yours faithfully,
A. C. Purday.

36, Chatsworth-road, Croydon, Surrey,
December 5, 1921.

To the Editor of Engineering.

Sir,—Will you permit me to refer to the last part of "Old Engineer's" letter of November 29, 1921; my experience during the last few months is, that there are at present as few openings for "capable experienced engineers" as for any others, if there really are, I wish I knew of them.

I am glad to see a distinction made between "men of little experience" and the more experienced, as to-day too much weight is immediately given to the qualification of a completed University course, while experience is given second place.

I am, &c.,
Glasgow, December 5, 1921. "Reader."

To the Editor of Engineering.

Sir,—I was very much intrigued, but not offended to read the letter from "An Old Engineer," evidently written from a position of pecuniary security and with a worthy regard for a noble profession in which I have worked for nearly thirty years, not without some success.

"Old Engineer's" letter does not refute my statements nor is it informative. As I read it, it can be condensed to an assumption that a young engineer, perhaps better qualified than an old engineer, although lacking his experience, is presumptious in expecting a remuneration that, while it would support him in comfort as a single man, would not permit him to start a home and keep a wife and family.

"Old Engineer" insinuates that my letter might "do harm to the profession." In view of the ultimate good that must ensue from the consideration of the subject this charge may be ignored. It might interest "Old Engineer" to know that some years ago I was invited to give my "mischievous" views before the Calcutta Institution of Electrical Engineers. Then he continues thus: "Engineers soon find out what men are worth . . . and rapidly increase their salaries." Yes, but some have first to woo and secure an employer, and they are a shy lot these days; regarding the latter part—well, it will be surprising, but welcome news to many faithful servants.

The charge that my letter is unbalanced does not trouble me as your readers will, I hope, decide, and not my critic. Further, I venture to ask wherein lies his fear? If the engineering profession is sound as a means of earning a good living my original letter washes out. If it is not—why be an ostrich and bury one's head in the sand?

In my letter I endeavoured to keep out the personal element, but "Old Engineer" seems to think I am a young engineer jealous of the "dud" plumber—your other correspondent read my letter with intelligence and understanding. I quite agree that 350*l.* is a sum that any young engineer would be thankful for, even at the present price of money—I should have been glad of it instead of the 25*s.* a week which I was earning at the age of 23.

As regards going abroad; when a young man is educated, and trained to be a citizen of his native country he has every right to expect to earn his living in it—even as an engineer. It may be that one, successful abroad, answered his country's call and returned to help defend his own islands, and the natives thereof—to say nothing of the other inhabitants.

Presumably "Old Engineer" is so placed that he has not to re-create the capital he lost during the war, make new friends in place of those who have "gone West" during a temporary absence from his country, and, in short, begin where he left off at the end of his apprenticeship. I can only thank "Old Engineer" for his criticism, as it serves as a grindstone for my steel.

Yours, &c.,
December 7, 1921. "Slide Rule."

To the Editor of Engineering.

Sir,—With reference to the above correspondence, I can only approach this matter as a civil engineer as defined in the more popularly accepted meaning of that term. "Slide Rule" undoubtedly summarises the condition of affairs very fairly. The salary in a municipal county or railway divisional engineer's office as a chief assistant for a man of 40 (? is he a young engineer) is on an average from about 370*l.* to 470*l.* per annum. So far from "Slide Rule's" letter doing harm to the profession, the giving of such paltry salaries does the harm.

It is quite evident that there are not enough positions of, say, city, municipal, county, railway district or divisional engineers to go round to those who are thoroughly competent for the jobs, and apart from the fact that many of these go by favour and influence, and while admitting that those holding these positions are not overpaid, the disparity in the salaries of the two positions, *i.e.*, between the chief and his chief assistant, is too great. A man cannot hold (rightly so) the position of chief assistant without being thoroughly qualified and competent, and as I said above, there are not enough jobs to go round, but surely it is quite evident that conditions are not healthy if chief assistants cannot afford to give their sons an education and training similar to what they had themselves.

The sooner the professional engineers have a union, not an emasculated one like the "Society of Technical Engineers," the better it will be for the profession. The Council of the Institution of Civil Engineers do nothing apart from expressing pious hopes, no doubt with their tongues in their cheeks.

"Slide Rule" is quite right, the supply is greater than the demand, and is partly due to the evils of subsidies, viz., the enormous increase of State and rate-aided technical colleges and universities. So far as the engineering branches of these institutions are concerned, a step in the right direction would be to insist on the fees entirely supporting them. Perhaps this information may be of use to Sir Eric Geddes.

Yours faithfully,
December 7, 1921. "B.Sc.Assoc.M.Inst.C.E."

"THE LOCOMOTIVE BOILER EXPLOSION AT BUXTON."

To the Editor of Engineering.

Sir,—With reference to the article appearing in your issue of December 2, on the locomotive boiler explosion at Buxton. My attention has been drawn to the fact that it is stated that Mr. Denning, assistant works manager, informed the coroner "it was last repaired by Messrs. Beardmore and went through the repair test up to 100 lb. pressure." I beg to say that this is an inaccuracy, as Mr. Denning did not know what test the boiler had been put through at Beardmore's, and suggested that Messrs. Beardmore's representative should be called upon for this information.

As the boiler was actually tested to 205 lb. hydraulic pressure and 200 lb. steam pressure before leaving Messrs. Beardmore's works, I hope you will contradict what is undoubtedly a printer's error.

Yours faithfully,
Hewitt Beames.

London and North-Western Railway, Chief Mechanical Engineer's Office, Crewe, December 6, 1921.

[We are obliged to Mr. Beames for the correction he has forwarded. The error, however, was not a typographical one, but occurred in the report of the inquest which was supplied to us.—Ed. E.]

"THE FLOW OF METAL DURING FORGING."

To the Editor of Engineering.

Sir,—I have been much interested in the recent letters and article on "The Flow of Metal during Forging." I was disappointed in not reading one letter from either a blacksmith or a forgeman. It is a very interesting subject from a practical point of view. I have been foreman more or less since 1904 and have smithy and forge experience gained by over thirty years' work with power hammers, from 3 cwt. to 3 tons, and forging presses from 800 tons to 1,500 tons. Both these machines are useful for certain classes of work; the hammer will do as good work as a forging press and the metal will flow as easily with a hammer as a press, provided the material is not too large, for the weight or effect of the blow. The material will retain the heat longer with the hammer than the press, for the friction is greater. No doubt for billets of 20 in. diameter and upwards the press is the most efficient machine. As a rule the hammer causes the metal to flow more on the surface and does not penetrate into the centre of the material, whereas the press penetrates to the heart, and the metal flows more from the heart and less on the surface. Before uniform flow of material can be achieved some other method will require to be invented. In shell forging the metal will flow evenly with a round-nosed punch, providing the metal has sufficient heat; if not, it will tear the metal the same as when punching a hole in a plate. Trusting this simple practical explanation will be acceptable.

Yours faithfully,
Robert Keddie.

12, Venus-road, Eltham, S.E. 9, December 5, 1921.

To the Editor of Engineering.

Sir,—I have not, unfortunately, yet seen Mr. Massey's original paper, but I notice that in your review you say that he used wax billets, but, in the note to my letter you refer to plasticine billets. Wax is a vague term; most waxes are, in my opinion, unsuitable for this purpose as being too brittle. I was never successful in producing the large and well-defined cone in the base with plasticine billets, except when artificial piping was present. So long as the material was homogeneous, nothing of this kind appeared, and I am myself quite confident that no cone of metal is carried in front of the punch. If it were, then I should expect that every forging, whether the original billet were sound or not, would exhibit the same defect.

I cannot imagine that such a cone could be carried in front of the punch for its whole stroke without producing a shearing and consequent area of discontinuity along the inclined surfaces of the cone.

Your obedient servant,
A. Dobree.

104, Victoria-street, Westminster, S.W. 1,
December 3, 1921.

PROTECTION OF MERCHANT SHIPS AGAINST SUBMARINES.

*Note on Some Proposals made During the War for Protecting Merchant Ships against Submarines.**

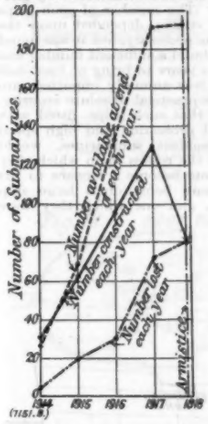
By Sir E. H. T. D'ENCOURT, K.C.B., F.R.S., D.Sc. (Hon. Fellow).

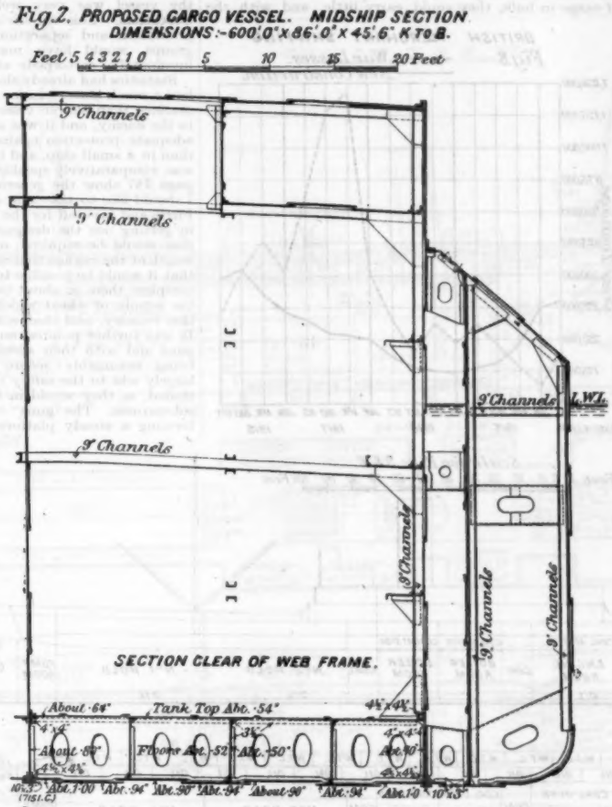
DURING the war a great many proposals were made for dealing with the submarine menace. These naturally divide themselves into offensive and defensive provisions, and I do not propose in this Note to deal at all with the former, but to confine myself more especially to one particular phase of the latter class of measures which were considered at different times. Although this is naturally now largely a matter of history, still I venture to think that a further consideration of some aspects of the situation will be interesting to this Institution, and might possibly be useful in the future.

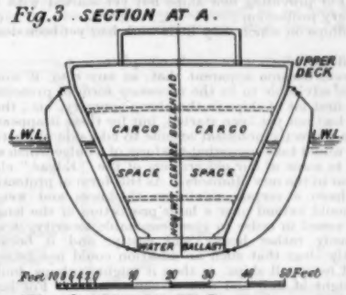
During quite the early part of the war the Germans had very few submarines, but as the war advanced they gradually increased their numbers, until at the close they had, as will be seen from the annexed curves (Fig. 1), a very large number, amounting to nearly 200; but it was not until after the war had been in progress for more than a year that the unrestricted submarine warfare began, and the destruction wrought by submarines on our commerce was such that, in about one and a-half to two years from the beginning of the war, the adequate supply of our munitions, food and other requirements was seriously threatened. How serious this was likely to become was hardly realised by many until the campaign was in full swing; but at the Admiralty the actual figures showed how at the end of 1915 and the beginning of 1916 the menace was gradually increasing.

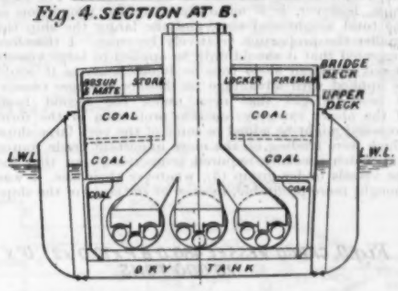
It became necessary, therefore, to explore the whole question from every side, and it is the object of this Note to show that this was done not only from the aspect of making all sorts of provision for attacking, harassing and destroying the enemy submarines, but also from the point of view of defending and protecting our merchant ships when attacked. I hope also to draw special attention to the proposals considered for so improving or altering the actual structure of ships as to prevent them sinking when struck by a torpedo. I do not propose, therefore, to give particulars of all the proposals made, many of which were tried, including various arrangements of torpedo nets, rigid guards and shields, which were arranged to be towed alongside ships. Many of these were found to have considerable value but presented great difficulties in use when the ship was under way, and in stowing and getting out when required. Nor will I allude to the great number of inventions, many of which were actually fitted for exploding mines before they made contact with the ship.

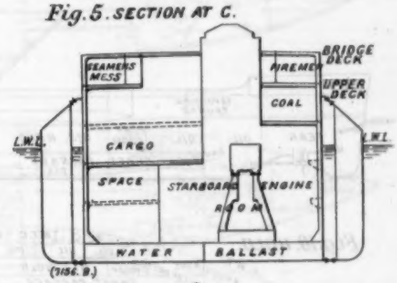
The Admiralty had, as you are aware, made a series of very useful experiments on the protection of ships against submarines shortly before the war and carried them on progressively after the war had begun. As the result of these experiments, which were finally tried on the full-size scale, it was demonstrated that it was possible, and indeed not very difficult, to give ships adequate protection against the attack of existing torpedoes. This having been proved in the case of war-

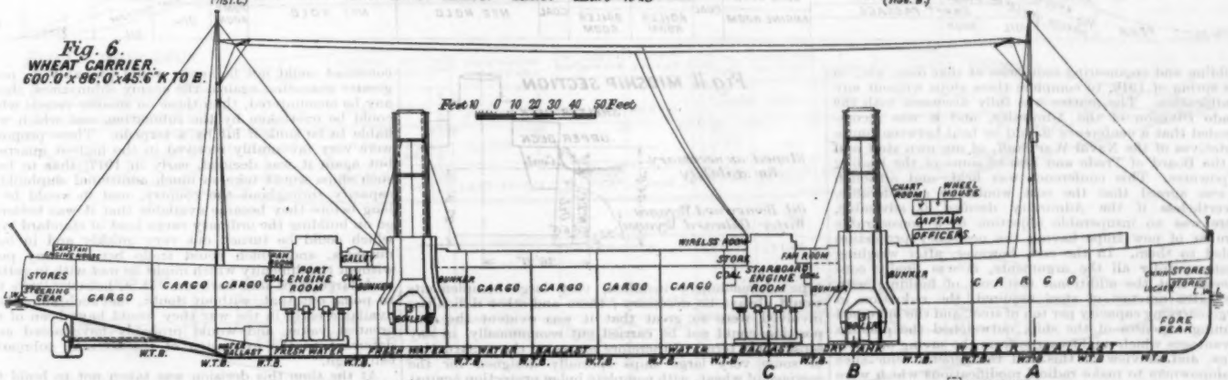


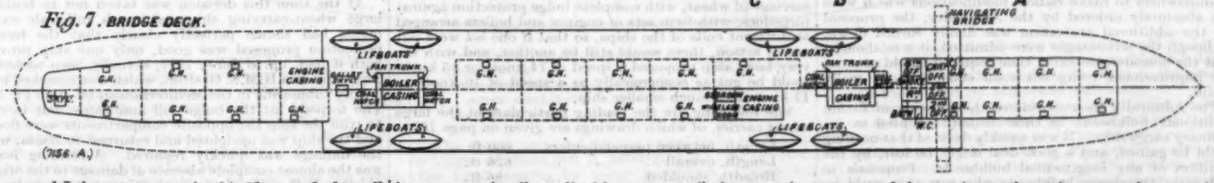












* Paper read before the North-East Coast Institution of Engineers and Shipbuilders, at Newcastle-on-Tyne, December 2, 1921.

ships, it naturally followed that the same form of protection might be fitted to merchant ships to give them similar protection against enemy torpedoes, provided the practical difficulties could be overcome. I suggested this to the Board, and received instructions to inquire fully into the matter and report.

It appeared to me that the matter should be considered under three heads, viz. :—

(1) For providing new ships not yet started with the necessary protection ;

(2) Ships on which very little work had yet been done ; and

(3) Ships which were nearly complete.

It soon became apparent that, at any rate, it would only be advisable to fit the necessary form of protection to the first lot of ships in the above category, viz., those which had not yet been started, but for these it appeared to be a perfectly practical scheme to add side protection which would take somewhat the form of a bulge which was added to some of our old cruisers of the "Edgar" class and also to the new Monitors. As this form of protection must have a certain minimum thickness and weight and should extend over a large proportion of the length of the vessel in order to give reasonable security, it was necessarily rather heavy and costly, and it became perfectly clear that such an addition could not be considered for small ships, as then it might perhaps double the weight of hull and cost of construction. For large ships, however, it is naturally a smaller proportion of the total weight and cost, and the larger the ship the smaller the proportion relatively becomes. I therefore suggested that it should only be applied to large vessels of not less than 8,000 tons or 10,000 tons, as it could be applied with advantage to these or to larger vessels. It was thought that even under the second head of the above category, outside protection of the form proposed might be added to some of the very large ships which were trading on the more important trade routes and which specially required protection ; but that for the vessels under group (3), whatever their size, it was thought more profitable, in view of the state of the shipbuilding and engineering industries at that date, viz., in the spring of 1916, to complete these ships without any modification. The matter was fully discussed with the Trade Division of the Admiralty, and it was recommended that a conference should be held between representatives of the Naval War Staff, of my own staff and of the Board of Trade and also of some of the leading shipowners. This conference was held, and although it was agreed that the cost would be considerable, nevertheless if the Admiralty deemed it advisable, there was no insuperable objection to a considerable number of new ships having the necessary protection added to them. In the end, however, after weighing most carefully all the arguments, it was finally considered that the additional first cost of building with the extra amount of steel required, the reduction in cargo-carrying capacity per ton of steel, and the increased running expenses of the ship, outweighed the possible advantages which might accrue from the saving of a few ships, and in view of this and the general reluctance of shipowners to make radical modifications which were not absolutely ordered by the Admiralty, the proposal for the additional protection was finally turned down. Although the advantages were admitted, it was thought that the considerable extra time required would prevent the improvement being felt soon enough to be really useful.

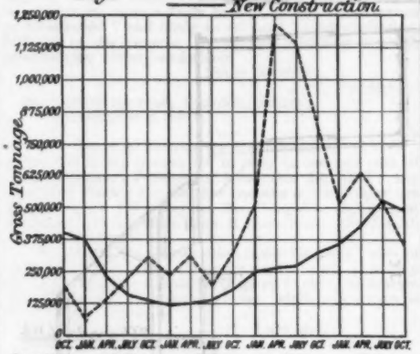
The Admiralty then considered the question of fitting additional bulkheads to those usually adopted in an ordinary cargo ship. It was quickly decided that nothing could be gained, and a good deal might be lost, by the addition of any longitudinal bulkheads. Proposals to add extra transverse bulkheads wherever this could be done were fully considered, but in view of the difficulty of getting work done at that time, when the whole demands of the country for steel and for shipbuilding were devoted to the provision of warships, this proposal was also not adopted.

In the standard ships the bulkheads were so arranged as to give the best spacing possible with a view to enabling the vessels to withstand a certain amount of damage, due regard being had to the cargo requirements of the vessels.

Referring to the demand for steel, it is of interest to note the immensity of the requirements—for shells alone the need amounted to the tremendous quantity of some 4,000,000 tons per annum, not counting the requirements for guns, and the many other engines of war.

Towards the end of 1916 and early in 1917, the enemy submarine campaign became more threatening than ever, and a good number of ships carrying various supplies to this country, including wheat, on which our existence depended, were being sunk ; and I received instructions to inquire into the possibility of using old warships for importing wheat. After examining this very carefully, it quickly became evident that this proposal was not feasible. The ships were ill-adapted to the carriage of cargo in bulk, they could carry little, and with the

Fig. 8. BRITISH MERCHANT SHIPPING — War Losses. — New Construction.



type of machinery installed, very large complements would always be necessary ; these and other difficulties involved were so great that it was evident the proposition could not be carried out economically, in any sense of the term. I therefore suggested the construction of some very large ships specially designed for the carriage of wheat, with complete bulge protection against torpedoes, with twin sets of engines and boilers arranged at different ends of the ships, so that if one set were put out of action, there would still be another, and with the very large ship proposed a speed of 14 knots or 15 knots could be got as economically as a speed of 10 knots or 11 knots in a much smaller ship.

The following are the leading particulars of the large wheat carrier, of which drawings are given on page 787 :

Length, between perpendiculars	600 ft.
Length, overall	626 ft.
Breadth, moulded	86 ft.
Depth, keel to beams	45 ft. 6 in.
Load draught	31 ft. 6 in.
Displacement	34,000 tons
Deadweight	19,000 tons
Speed at sea	14 knots
Indicated horse-power of twin-screw engines	10,000

The vessel was designed with a straight stem and a cruiser stern. The under-water protection consisted of a bulge extending over almost the whole length of the vessel, the width of the bulge being such that the hull proper would be about 11 ft. 6 in. from the seat of a possible under-water explosion. The bulge was to be divided by a longitudinal bulkhead into two compartments, the outer one being empty and the inner one containing water. The boilers were arranged in two boiler rooms, one forward and the other abaft amidships. Immediately abaft each boiler room was an engine room, that forward containing the starboard engine and that aft, the port engine. The cargo holds were so arranged that there were four holds forward of the forward boiler room, four between the two groups of machinery and three abaft the port engine room. Abreast each engine room was also a cargo hold. It will thus be seen that the vessel was very well sub-divided by transverse bulkheads. This sub-division, together with the bulge protection and separation of the machinery into two groups, would have made these vessels practically invulnerable to torpedo attack.

Statistics had already shown that ships of over 11 knots had a much better chance of avoiding the attack of submarines than slower vessels, which fell an easy victim to the enemy, and it was also much easier to give really adequate protection against torpedoes in a large rather than in a small ship, and the proportion of added weight was, comparatively speaking, insignificant. The plans on page 787 show the general character of these ships, and I should like to take this opportunity of thanking Lord Pirrie and his staff for the very able assistance they gave in getting out the designs. The number of such ships that would be required, of course, depended upon the length of the voyage that was necessary, but it was found that it would be possible to build a sufficient number and complete them in about two years to bring at least half the supply of wheat which was annually imported into this country, and that with practical absolute security. It was further pointed out that such ships, fitted with guns and with their special protection and high speed being reasonably secure against submarines, would largely add to the safety of the routes upon which they traded, as they would in time become a menace to the submarines. The guns' crews being on a large ship forming a steady platform, and one which they were

Fig. 9. CARGO VESSEL 480'0" B.P. x 72'0" x 27'0" x 20,000 TONS.

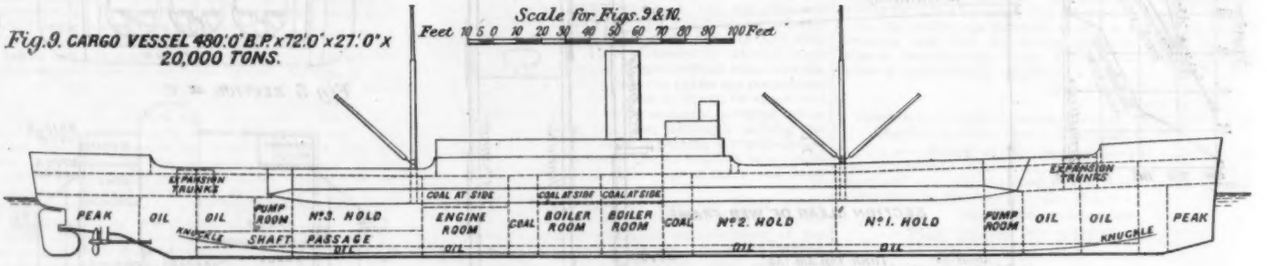


Fig. 10. HOLD.

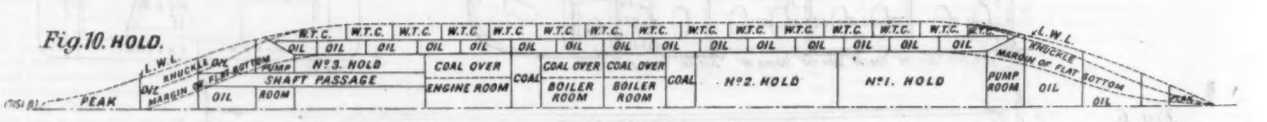
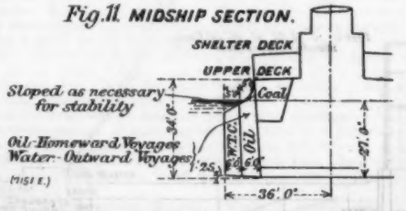


Fig. 11. MIDSHIP SECTION.



confident could not be sunk, would probably do much greater execution against the enemy submarines, should any be encountered, than those on smaller vessels which could be overtaken by the submarine, and which were liable to be sunk if hit by a torpedo. These proposals were very favourably received in the highest quarters ; but again it was decided, early in 1917, that to build such ships would take so much additional shipbuilding capacity throughout the country, and it would be so long before they became available that it was better to go on building the ordinary cargo boat of standard type, which could be turned out very quickly and in large numbers, and which could trade between any ports without the difficulty which might be met with in getting such large ships into harbour. It is, however, only fair to point out that, without doubt, had such ships been available early in the war they would have been of the greatest value, and would probably have acted as a deterrent to the expansion of the German submarine campaign.

At the time this decision was taken not to build the large wheat-carrying ships, although full-scale experiments had shown perfectly clearly that the form of protection proposed was good, only one ship provided with it had, up to June, 1917, actually been torpedoed. That ship was H.M.S. Grafton, which was attacked by an enemy submarine in the Mediterranean on June 11, 1917. The torpedo hit the bulge full amidships, but in order to trim the ship the opposite compartments were flooded and the ship was uprighted and returned to Malta, where the damage was quickly repaired. A striking feature was the almost complete absence of damage to the original old thin hull of the Grafton, showing that the bulge had provided adequate protection. This was confirmed in 1918 when two sister vessels of the Grafton were both torpedoed. The bulges of these vessels so protected the hulls that the damage sustained by the latter was of the very slightest. Later in 1917, however, both the Erebus and Terror, two of our monitors, were hit (one by a distant controlled boat and the other by torpedoes) and damaged, but again the bulges protected the hulls from serious damage, and so kept the vessels afloat. In view of this further evidence of the efficiency of this form of protection, submissions were again made to give under-water protection to merchant ships with a view to keeping

them afloat. It was then admitted that if bulge protection had been fitted early in the war to the ships first torpedoed, a large number of ships would probably have been saved, and the actual weight of steel and the work of replacing lost ships would have been enormously reduced. In fact the gain in the actual saving of steel and of supplies, munitions, grain, &c., would have been very welcome at the most difficult period. Further, had the enemy discovered that attacking our ships with torpedoes did not achieve the result expected, and that they were reasonably immune from attack, it might in the earlier stages of the war have prevented the renewed virulence of the German submarine campaign, and instead of having to build an enormous number of ships, of which a large proportion was being continually lost preparations for an enormous output of these with this in view need not have been on such a large scale, either in this country or in America. Fig. 8, on page 788, is a chart showing the tonnage of merchant vessels built and lost by enemy action during the war.

Of course, it is very easy to be wise after the event, and it is very difficult at the time to give a correct decision upon points where there are many pros and cons, and when it is quite impossible to say how long the period of stress may continue; but I think that when fairly considered now in the light of what has happened, it shows that it would certainly have been of advantage to fit up a certain number of ships with a form of protection which was proved adequate, and which might have been of very great benefit.

I have not given a complete list of all the proposals which were made from time to time, but Figs. 9 to 11, on page 788, show a design embodying this form of protection, and which was specially devised to carry oil in the wing compartments and ordinary cargo in the regular holds. The proposal for building these ships, however, met with the same fate as that for the wheat carrier.

The following are the leading particulars of the design of the protected cargo carrier and oil tanker:—

Length overall	500 ft.
Length between perpendiculars	480 ft.
Breadth, extreme over bulges...	72 ft.
Depth to upper deck	34 ft.
Draught	27 ft.
Corresponding displacement ...	20,000 tons
Deadweight	12,500 tons
Indicated horse-power of twin-screw machinery	6,000.
Maximum speed	13½ knots.

The design provided for the vessel to be protected for a length of about 300 ft. amidships (*i.e.*, 60 per cent. of the total length) by bulge protection of such width that the hull proper would be about 11 ft. (on the average) from the seat of a possible underwater explosion. The bulge was to be divided by a longitudinal bulkhead into two compartments, the outer one being empty and the inner one containing water (on outward voyages) or oil (on homeward voyages). The vessels would then have carried a large addition to her cargo of oil on homeward voyages. The amidships protected portion of the vessel was arranged with two cargo holds forward and one aft of the machinery compartments. Before and abaft the cargo holds, *i.e.*, beyond the protected portion of the vessel, the construction was to be similar to that of an oil tanker, so that, for homeward voyages, the vessel could carry a cargo of oil in these tanks as well as in the inner compartments of the bulges and the double bottom compartments, making a total of 5,000 tons of oil fuel. Pump rooms were to be fitted forward and aft separating the cargo holds from the oil tanks. The cargo spaces amidships were of 280,000 cub. ft. capacity. The boilers were arranged in two boiler rooms with cross bunkers separating the forward boiler room from the cargo holds and the after boiler room from the engine room. The profile of the vessel was arranged to be practically symmetrical about amidships so that the "double-ended" appearance thereby obtained would render attack by submarine difficult. As will be seen from the drawings on page 788 and the foregoing description, the vessel was well subdivided by transverse bulkheads.

It is interesting to note that in 1915 the Admiralty for the fuel supply of the Fleet, designed and built some special oil-carrying ships of 15 knots speed and carrying 5,000 tons of oil. Plans of the general arrangements and a constructional drawing of the midship section of these ships are given above. Six of these vessels were built, and were not only used for accompanying the Fleet, but were also used for bringing oil overseas. They were very well subdivided, and were reasonably safe from at least one torpedo, but their high speed was probably their best protection.

These vessels, which were known as the "Plumleaf" class, were ordered in August, 1915, and completed in the first half of 1917.

They proved of great value at one period when we had lost a good many cargoes of oil. They were employed in bringing cargoes of oil from the Gulf of

Fig. 12. 5000 TON OILER.

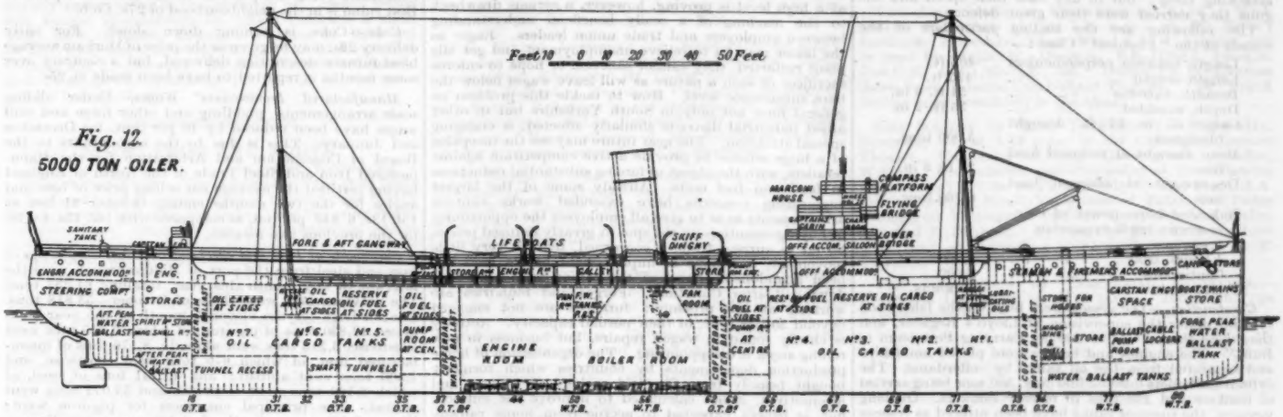


Fig. 13. POOP DECK. BRIDGE DECK. FORECASTLE DECK.

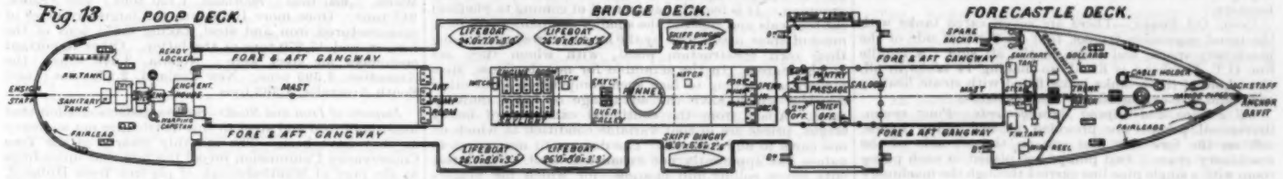


Fig. 14. UPPER DECK.

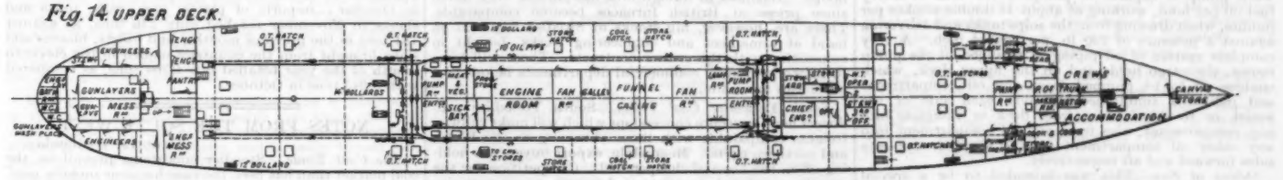


Fig. 15. MAIN DECK.

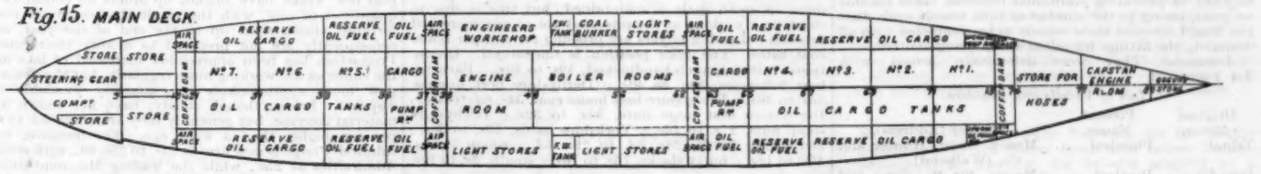
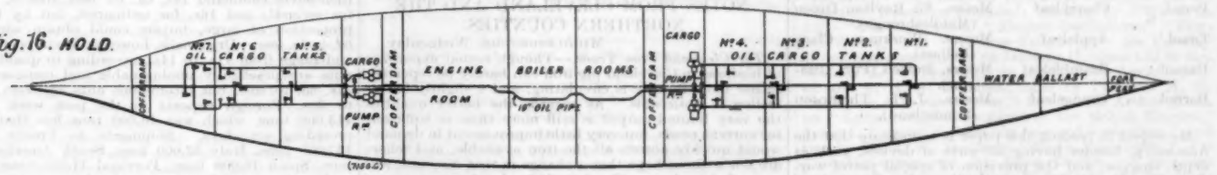


Fig. 16. HOLD.



Mexico and elsewhere during this period. They maintained an ocean speed of over 12½ knots, and on approaching the danger zones, this speed was increased, sometimes to 16 knots, with the result that only one of these vessels was ever damaged. This was the Appleleaf, which was damaged either by mine or torpedo in November, 1917. She was repaired and on service again in about four months from this date. It is probable that their immunity from attack was partly due to their appearance, which differed materially from that of the ordinary tanker, and prevented the submarine commanders, who had instructions specially to attack oil-fuel ships, from attacking them; but in any case their speed and the guns they carried were their great defence.

The following are the leading particulars of the vessels of the "Plumleaf" Class:—

Length between perpendiculars	405 ft.
Length overall	425 ft.
Breadth, extreme	54 ft. 6 in.
Depth, moulded	35 ft. 2 in.
Cargo oil in 25 ft. draught (designed)	5,000 tons.
Mean draught at assigned load line	27 ft. 8 in.
Deadweight at assigned load line	6,760 tons.
Indicated horse-power of twin-screw triple-expansion engines—	
4 hours' trial	6,750
Continuous	6,000
Trial speeds	16 knots.

Construction.—The vessels were built on the Isherwood system, under the supervision of Lloyd's Register, and they were classed: "+ 100 A1 Carrying Petroleum in Bulk." The engines and boilers were placed amidships and separated from the oil tanks by cofferdams. The cylindrical boilers burn oil fuel only, 500 tons being carried in bunkers and 250 tons in reserve bunkers. On long voyages, the summer tanks have been utilised as reserve bunkers.

Cargo Oil Tanks.—There are seven cargo tanks with the usual expansion trunks, four on the fore side of the machinery space, and three on the aft side. A middle line O.T. bulkhead is fitted, so making 14 tanks in all, the whole of these tanks being fitted with steam heating coils and fire-extinguishing arrangements.

Oil Pumps and Piping Arrangements.—Four steam-driven oil pumps are provided in two pump rooms, one on the fore side and one on the aft side of the machinery space; two pumps are placed in each pump room with a single pipe line carried through the machinery space to connect up the forward and after pumps. Each pump is capable of pumping 100 tons of heavy fuel oil per hour, working at about 15 double strokes per minute, when drawing from the ships tanks and delivering against a pressure of 250 lb. per square inch. A very complete system of oil piping is arranged in the pump rooms, the cargo holds and on the upper deck, which enables oil to be pumped from any oil compartment and delivered simultaneously over each side of the vessel, or to ships' tanks from deck or alongside into any compartment, also from any oil compartment into any other oil compartment on the same or opposite sides forward and aft respectively.

Oiling at Sea.—This was intended to be a special feature of these six vessels as fleet auxiliaries but the urgency of providing additional overseas oilers became so great, owing to the number of such vessels sunk, that the Board directed these vessels to be completed with all despatch, the fittings for oiling at sea being omitted.

Armament.—They were defensively armed with 2-4·7 guns aft.

List of Vessels and Builders.

Original Name.	Present Name.	Builder (Address).
Trinol ...	Plumleaf ...	Messrs. Swan, Hunter and Co. (Wallsend).
Gypol ...	Pearleaf ...	Messrs. Sir W. Gray and Co. (West Hartlepool).
Persol ...	Cherryleaf ...	Messrs. Sir Raylton Dixon (Middlesbrough).
Texol ...	Appleleaf ...	Messrs. Workman Clark (Belfast).
Rumol ...	Brambleleaf	Messrs. Russell (Port Glasgow).
Bornol ...	Orangeleaf ...	Messrs. J. L. Thompson (Sunderland).

My object in reading this paper is to indicate that the Admiralty, besides having all sorts of devices, such as depth charges, and the provision of special patrol warships, &c., for the destruction of the enemy submarines, also had continually in view the employment of all available means for protecting the ships carrying the supplies upon which our existence depended. This aspect of the proposition, viz., the defensive, has not been so fully realised as the more interesting offensive methods used against the submarines. Finally, a combination of the offensive and defensive, as the convoy system developed, overcame the difficulties, and gradually the destruction of our own ships diminished and that of the enemy submarines increased. This could not have been brought about had it not been for the indomitable courage shown throughout by the *personnel* of the Navy on the one hand, and of the officers and men of the mercantile marine on the other.

Electrification of South African Railways.—The Department of Overseas Trade is informed that the South African Railways and Harbours Board have now definitely decided on the electrification of 171 miles of railway from Glencoe to Pietermaritzburg.

NOTES FROM SOUTH YORKSHIRE.

Sheffield, Wednesday.

Iron and Steel.—Failure to arrive at a stabilisation of values is, in the opinion of many of the leading engineering masters, one of the main obstacles to trade expansion. Users of steel, tools and engineering plant in the Colonies, South America, and the Eastern markets are waiting to place orders, but will not move beyond hand-to-mouth purchases until firm quotations are available. Futher applications are being made locally for wage reductions to cover the coil spring, steel-melting, and tool trades. The maintenance of the cost of living at a high level is proving, however, a serious drawback to the reaching of a really beneficial understanding between employers and trade union leaders. Eager as the latter may be to relieve unemployment and get idle plant restarted, they cannot sanction or hope to enforce sacrifices of such a nature as will leave wages below the bare subsistence level. How to tackle this problem on general lines not only in South Yorkshire but in other allied industrial districts similarly affected, is engaging special attention. The near future may see the inception of a huge scheme to provide active competition against retailers, with the object of forcing substantial reductions in food and fuel costs. Already some of the largest engineering concerns have extended works canteen arrangements so as to give all employees the opportunity of buying essentials on the spot at greatly reduced prices. So far as current trade is concerned, there is very little movement, and hope of improvement before 1922 has been abandoned. Some of the rolling mills have shut down till after Christmas. Forges and foundries are working at low pressure; furnaces are not engaged beyond 30 per cent. of their normal capacity. Activity is chiefly found in wagon repairs, but business in new rolling-stock is disappointing. The organisation of home production departments by countries which formerly bought heavily from Sheffield makers of wagons and locomotives, is not calculated to improve the outlook, nor is benefit expected to accrue from home railway grouping. It is feared that instead of coming to Sheffield for renewals and repairs, the smaller companies will have most of their needs met by the larger railways possessing their own construction plant, with whom they are amalgamated. In the scramble for new business, steel makers are having to face keen competition from other districts which have the advantage of lower delivery rates. Apart from the continued existence of heavy stocks, prices are in that variable condition at which no one cares to buy forward. The downward movement in values has apparently not exhausted itself. The latest cuts cover rolling-mill charges—for which file makers have been pressing for some time—wire ropes, and steel hoops. Business in foreign ores has shrunk very much since prices at British furnaces became comparable. There are, however, big stocks of Swedish material on hand at armament and engineering works, bought in connection with the cruiser contracts. These will have to be worked off in commercial departments before new purchases are made.

South Yorkshire Coal Trade.—South Yorkshire producers hope to secure concessions which will make railway freights comparable with those obtaining to the Welsh and northern ports. Meanwhile, export buyers are holding off in the hope of cheaper fuel. Competition for the greatly restricted amount of business passing in industrial fuel for home use increases daily. The improvement in small fuels is maintained, but this is due to short time working at the pits, and not to any increased demand. London buyers are pressing for cheaper house coal rates. The coke position is unchanged. Quotations:—Best branch handpicked, 39*s.* to 40*s.*; Barnsley best Silkstone, 38*s.* to 40*s.*; Derbyshire best brights, 35*s.* to 36*s.*; Derbyshire best house coal, 34*s.* 6*d.* to 35*s.*; Derbyshire best large nuts, 30*s.* to 32*s.*; Derbyshire small nuts, 27*s.* to 29*s.*; Yorkshire hards, 29*s.* to 30*s.*; Derbyshire hards, 28*s.* 6*d.* to 29*s.* 6*d.*; rough slacks, 17*s.* to 18*s.*; nutty slacks, 15*s.* to 16*s.*; smalls, 5*s.* to 10*s.*

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

Middlesbrough, Wednesday.

The Cleveland Iron Trade.—Though actual expansion of business in Cleveland pig-iron can hardly be reported, rather more inquiry is circulating, and a slightly better feeling is noticeable. As regards the better qualities the very limited output is still more than is sufficient for current needs, but very little improvement in demand would quickly absorb all the iron available, and sellers are not without hope that a change in that direction will occur before long. No. 1 is 105*s.* for home purposes and 110*s.* for export, and No. 3 G.M.B. is 100*s.* for home use and 105*s.* for shipment abroad. The inferior grades are abundant and very slow of sale at makers' quotations, which are identical for home and export trade. No. 4 foundry is 95*s.*, No. 4 forge 90*s.*, mottled 85*s.*, and white iron 85*s.*

Hematite.—With output increasing by the restarting of idle furnaces, values of East Coast hematite are easy. Makers are untrammelled by agreements as regards prices, and as they are at liberty to make what charges they please there is keen competition for any orders in the market. No difficulty is now experienced in purchasing Nos. 1, 2 and 3 at 105*s.*, for home use or for despatch to foreign destinations. No. 1 is half-a-crown above mixed Nos.

Manufactured Iron and Steel.—Depression in manufactured iron and steel is unrelieved, and indeed though producers are sparing no effort to secure orders, at even rather below cost price, to keep their works partially employed, there seems no likelihood of any material improvement until the turn of the year. Manufacturers are prepared to accept foreign orders at substantially below the following rates which are named for home business:—Common iron bars, 12*l.* 10*s.*; iron rivets, 16*l.*; soft steel billets, 7*l.* 10*s.*; medium steel billets, 9*l.*; hard steel billets, 9*l.* 10*s.*; steel boiler plates, 16*l.*; steel ship, bridge and tank plates, 10*l.* 10*s.*; steel angles, 10*l.*; heavy sections of steel rails, 10*l.* 10*s.*; fish-plates, 15*l.* 10*s.*; black sheets, 14*l.*; and corrugated galvanised sheets, 17*l.* 10*s.*

Foreign Ore.—Nothing new of moment is noticeable in foreign ore. There is hardly any business doing, consumers being independent of the market at present. Best rubio is in the neighbourhood of 27*s.* f.o.b.

Coke.—Coke is coming down slowly. For early delivery 29*s.* may be given as the price of Durham average blast-furnace description delivered, but a contract over some months is reported to have been made at 25*s.*

Manufactured Ironworkers' Wages.—Under sliding scale arrangements puddling and other forge and mill wages have been reduced by 10 per cent. for December and January. This is due to the accountants to the Board of Conciliation and Arbitration for the Manufactured Iron and Steel Trade of the North of England having certified the average net selling price of bars and angles for the two months ending October 31 last at 15*l.* 13*s.* 6·84*d.* per ton, as compared with 16*l.* 13*s.* 4·77*d.* for the previous two months.

Shipments of Iron and Steel.—November shipments of iron and steel from the port of Middlesbrough were the heaviest of any month this year, totalling 61,237 tons. The previous best were those of October—53,818 tons. The loadings for the eleventh month of the year comprised 12,830 tons of pig-iron, of which 9,615 tons went coastwise, 3,215 tons went abroad; 8,176 tons of manufactured iron, of which 676 tons went coastwise, and 7,500 tons went abroad; and 40,231 tons of steel, of which 6,160 tons went coastwise and 34,071 tons went abroad. The principal customers for pig-iron were: Wales, 7,650 tons; Scotland, 1,120 tons; and France, 945 tons. Once more India was the largest receiver of manufactured iron and steel, taking 6,834 tons of the former, and 17,970 tons of the latter. Other important customers for steel were: Nigeria, 3,646 tons; the Argentine, 3,395 tons; New Zealand, 2,978 tons; and South Australia, 1,363 tons.

Imports of Iron and Steel.—Some satisfaction is felt that imports of iron and steel to this district are not so heavy as they have been. The monthly returns of the Tees Conservancy Commission reveal the fact that unloadings at the port of Middlesbrough of pig-iron from Holland, Belgium, France, Sweden and Germany last month amounted to 17,563 tons, as compared with 20,509 tons in October; imports of plates, bars, rails, joists and sheets in November reached only 236 tons, as against 781 tons in the previous month; and billets, blooms and slabs brought from the countries named in the eleventh month of the year totalled but 4,760 tons, as compared with 6,945 tons in October.

NOTES FROM THE SOUTH-WEST.

Cardiff, Wednesday.

The Coal Trade.—Steadier conditions prevail on the coal market than has been the case for some months past. This is due to the fact that colliery salesmen during the past few weeks have booked up orders for considerable quantities of coal, with the result that some are comfortably placed right up to the end of the year, and consequently are not prepared to modify their prices. Production has been appreciably increased of late and the collieries are working more regularly, but the demand now more approximates the quantity available for disposal. Prices, though steady, have not shown any material increase, but generally they are about 3*d.* to 6*d.* per ton higher than a week ago. For instance, best Admiralty large is now firm at 25*s.* to 25*s.* 6*d.*, with second Admiralties at 25*s.*, while the leading Monmouthshires realise from 23*s.* to 24*s.* Smalls continue scarce, and by themselves command 18*s.* 6*d.* for best steams, 17*s.* 6*d.* for seconds, and 16*s.* for ordinaries, but by taking a proportion of large, buyers could obtain supplies at 6*d.* to 1*s.* less. Dry smalls, however, are in poor request, and range from 11*s.* to 14*s.*, according to quality. Dry nuts are practically unobtainable and command from 37*s.* 6*d.* to 40*s.*, but bituminous nuts are from 27*s.* 6*d.* to 30*s.* Foreign exports in the past week totalled 415,000 tons, which was 10,000 tons less than in the preceding six days. Shipments to France totalled 137,000 tons, Italy 52,000 tons, South America 52,000 tons, Spain 16,000 tons, Portugal 11,000 tons, British coaling depots 67,000 tons, and other countries 80,000 tons.

Colliery Company's Big Loss.—The first report of a colliery company embracing the period of the two national coal strikes has just been issued, and shows a heavy loss. The report of the Blaenavon Company, Limited, which owns four collieries, three blast furnaces, a modern by-product coke-oven plant, a new tyre mill, seven Siemen's steel furnaces and steel mills in Monmouthshire, shows a loss for the twelve months ended September 30 last, of 107,352*l.*, of which 29,265*l.* was for coal supplied to workmen at less than the cost of production. In the previous year the company made a profit of 191,298*l.* and paid a dividend of 12½ per cent.

Dock Strike Continues.—No settlement has been reached in the dispute between the Shipping Federation and the South Wales dock pilots, riggers and boatmen in respect to the rates of pay of these men. It will be recalled that the Shipping Federation, after abortive negotiations, put into operation a new tariff, and the men refused to work vessels except at their own tariff.

Tugboatmen refused to handle vessels which did not employ pilots and boatmen, and the tugboat owners dismissed their crews. The pilots, boatmen and riggers then came out on strike and refused to handle any vessels. Up to the present the stoppage has hardly affected shipping, vessels being docked, undocked and shifted without the assistance of the disaffected men. It is understood that feelers have been put out by the men's side with a view to re-opening negotiations with the Shipping Federation, but so far no meeting has been arranged.

Iron and Steel.—The tone of the tin-plate market is slightly easier owing to the operation of "bear" sellers who bought speculatively on option contracts a short while back. Makers, however, continue to hold out for 22*s.*, while merchants are selling at 21*s.* 6*d.* for prompt delivery and 21*s.* forward. Galvanised sheets are steady, with 24-gauge corrugateds at 17*l.* to 17*l.* 5*s.*, and sheet and tin bars at 7*l.* 15*s.*

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scottish Steel Trade.—The conditions in the steel trade of Scotland have shown no signs of improvement during the past week, and with demand so poor the order books are very bare. Inquiries are more numerous again, but the resulting business is of small volume and it is very evident that buyers, while quite desirous of placing contracts, are holding back for still cheaper prices. The dealings which are taking place are mainly the minimum necessary for immediate requirements. Competition from the Continent has got gradually less on account of the uncertainty of delivery, but producers in the south are cutting rather keenly, and quite a fair amount of business has been secured by them. Export trade has not improved, and little change is expected in that direction until rates of exchange are better and the financial position abroad gets on to a better footing. Prices have remained steady, but at a meeting of the Scottish steel makers in Glasgow yesterday (Tuesday), it was resolved to make a reduction of 30*s.* per ton in the price of boiler plates for delivery in Scotland, the new quotation now being 14*l.* per ton, subject to the usual extras. The other current quotations are as follow:—Ship plates, 10*l.* 10*s.* per ton; and sections, 10*l.* per ton, net, delivered Glasgow stations.

Scottish Sheet Trade.—Prices Reduced.—There has been little change in the Scottish black steel sheet trade of late, and the last reduction in prices did not bring out much fresh business. The various works have been moving very slowly, and with the object of trying to improve matters the makers decided this week to make a further cut in prices, amounting to 10*s.* per ton. The basis price for ¼-in. sheets will now be 12*l.* 5*s.* per ton, net, delivered Glasgow or equal. Foreign inquiries for both black and corrugated sheets are a little better, and it is hoped that the new quotations will result in an increase in orders.

Malleable Iron Trade.—A stronger tone is noticeable in the West of Scotland malleable iron trade over the week, but the amount of business booked does not constitute a very heavy tonnage, and is easily turned out. Fresh inquiries are fair. The current price of "crown" bars is 12*l.* 10*s.* per ton.

Scottish Pig-Iron Trade.—The position of affairs in the Scottish pig-iron trade is no better, and the demand is barely equal to the output. Foundry and forge iron are little sought after, and the various steel works are so quiet that the consumption of hematite iron is on quite a small scale. Prices continue to show a downward tendency, but even that fails to stimulate the demand; however, every little helps, and it cannot be long now until a buying movement begins as industry in general is improving slowly. The current quotations may be taken as 6*l.* 5*s.* per ton for No. 1 foundry iron, and 6*l.* per ton for No. 3, at makers' works, and 6*l.* 5*s.* per ton for hematite delivered at the steel works.

Railway Rates for Iron and Steel.—Although concessions have been made in prices all round, the railway companies have not yet come into line, with the result that a point has almost been reached when further reductions will largely depend upon the amounts the railway companies are prepared to take off their rates. The matter has been under discussion lately, and this week a meeting took place between representatives of the Scottish steel makers, ironmasters, bar iron and sheet manufacturers, and the general managers of the Caledonain, the Glasgow and South-Western, and the North British Railway Companies. The iron and steel trades representatives urged upon the railway companies the imperative need for an immediate and substantial reduction in railway rates before there was any hope of business reviving, or even if the present modified operations were to be continued. The managers agreed to lay before their various Boards of Directors the representations which had been made for their consideration.

BULLETIN OF THE CLEVELAND TECHNICAL INSTITUTE.—This Institute now issues a monthly bulletin of about 30 pages, measuring 8¼ in. by 5½ in., giving abstracts from British and foreign technical journals on analysis and industrial chemistry, fuel and fuel technology, blast-furnace practice and steel-making, chemistry and physics, and iron and steel, general engineering, electrical engineering, foundry practice, non-ferrous alloys, ship-building and marine engineering, and mining engineering. Every abstract can be cut out for filing purposes. The director and secretary is Mr. E. L. Johnson, Corporation-road, Middlesbrough.

NOTICES OF MEETINGS.

THE JUNIOR INSTITUTION OF ENGINEERS.—Friday, December 9, at 7.30 p.m., at the Royal United Service Institution, Whitehall, S.W. 1, Mr. C. H. Wordingham, C.B.E., M.Inst.C.E., M.I.Mech.E., M.I.E.E., will deliver his Presidential Address. The retiring president, The Right Hon. the Lord Weir of Eastwood, P.C., D.L., LL.D., will take the chair.

THE SCIENTIFIC SOCIETY OF THE ROYAL TECHNICAL COLLEGE, GLASGOW.—Saturday, December 10, at 7.30 p.m., in the College, a Lecture on "Water Turbines," by Mr. D. M. Anderson, C.B.E.

THE MINING INSTITUTE OF SCOTLAND.—Saturday, December 10, at 3 p.m., in the Royal Technical College, George-street, Glasgow. Mr. David Penman's paper on "A New Method of Measuring Ventilating Resistances, with Special Reference to the Operation of Mine Fans in Combination" will be discussed. Mr. James Cooper's paper on "Measurements of Air Velocities and the Testing of Anemometers" will be discussed.

THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.—Saturday, December 10, at 2 p.m., in the Lecture Theatre of the Institute, Newcastle-upon-Tyne. A general discussion on the limitations of Coal-Cutting Machinery. The discussion will be opened by Colonel F. R. Simpson.

THE KEIGHLEY ASSOCIATION OF ENGINEERS.—Saturday, December 10, at 6.30 p.m., Joint Meeting with the Textile Society in the Assembly Room of the Cycling Club, Cavendish-street. Lecture by Dr. R. Whiddington, of the University, Leeds. Subject, "Wireless Telegraphy and Telephony."

THE ROYAL SOCIETY OF ARTS.—Monday, December 12, at 8 p.m.: Cantor Lecture, "Processes of Engraving and Etching," by Mr. Arthur M. Hind, O.B.E., M.A., Slade Professor of Fine Art in the University of Oxford (Lecture III). Wednesday, December 14, at 8 p.m.: Ordinary Meeting, "Trade with the Netherlands East Indies," by Sir Walter Beaupré Townley, K.C.M.G., Minister to the Netherlands, 1917–19. The Right Hon. Lord Emmott, G.C.M.G., G.B.E., will preside.

THE INSTITUTE OF TRANSPORT.—Monday, December 12, at 5.30 p.m., the Second Ordinary Meeting of the current session at the Institution of Civil Engineers, Great George-street, Westminster, S.W. 1. Paper on "The Future of British Railways," by Sir George Paish.

THE SURVEYORS' INSTITUTION.—Monday, December 12, when a paper will be read entitled "The Relation of Soil to Plant Growth, and in Particular when Influenced by the Presence or Absence of Lime," by Mr. A. A. Hudson, K.C. The chair will be taken at 8 p.m.

THE BRADFORD ENGINEERING SOCIETY.—Monday, December 12, at 7.30 p.m., Lecture in the Hall of the Bradford Technical College, by Mr. W. H. Hatfield, D.Sc., of Sheffield, on "Metallography for Ironfounders," illustrated by lantern slides.

THE SHEFFIELD ASSOCIATION OF METALLURGISTS AND METALLURGICAL CHEMISTS.—Tuesday, December 13, "Corrosion of Metals," by Mr. F. Rogers, D.Eng., B.A., M.Sc.; Tuesday, December 20, "The Effect of Solders on Beta Brasses," by Mr. J. H. S. Dickenson, M.Inst.Met.

THE INSTITUTE OF METALS.—Tuesday, December 13, at 7.30 p.m., in the Rooms of the Institution of Engineers and Shipbuilders in Scotland, 39, Elmbank-crescent, Glasgow. A paper by Mr. G. E. Fleming (of Messrs. John Dewrance and Co.), on "White Metals," will be read and discussed.

THE INSTITUTION OF ELECTRICAL ENGINEERS (SCOTTISH CENTRE).—Tuesday, December 13, at 7.30 p.m., in the Rooms, 207, Bath-street, Glasgow. Paper, with illustrations, by Messrs. L. J. Steel and H. Martin, on "The Cyc-Arc Process of Automatic Electric Welding," will be read and discussed.

THE ILLUMINATING ENGINEERING SOCIETY.—Tuesday, December 13, at 8 p.m., at the House of the Royal Society of Arts, John-street, Adelphi, London. A discussion on "Progress in Gas Lighting in Relation to Illuminating Engineering" will be opened by Mr. W. J. Sandeman (Croydon Gas Company).

THE MANCHESTER METALLURGICAL SOCIETY.—Tuesday, December 13, at 7 p.m., at the College of Technology, Manchester, a paper on "White Metals," by Mr. A. H. Munday, will be read and discussed.

THE INSTITUTION OF CIVIL ENGINEERS.—Tuesday, December 13, at 6 p.m. Papers to be read: "Deep-Water Quays: General Considerations of Design," by Mr. Ernest Latham, M.Inst.C.E.; "On the Stability of Deep-Water Quay-Walls," by Mr. Francis Ernest Wentworth-Sheilds, O.B.E., M.Inst.C.E. And ballot for new members.

THE INSTITUTION OF ELECTRICAL ENGINEERS: NORTH MIDLAND CENTRE.—Tuesday, December 13, at 7 p.m., at the Metropole, King-street, Leeds. Paper by Mr. L. H. A. Carr, Member, on "Induction Type Synchronous Motors."

THE INSTITUTION OF AUTOMOBILE ENGINEERS.—Wednesday, December 14, at 8 p.m., at the Institution of Mechanical Engineers, Storey's Gate, St. James's Park, London, S.W. 1, Mr. H. F. L. Orcutt will read a paper entitled "Motor Car Gear Boxes."

THE ASSOCIATION OF DROP-FORGERS AND STAMPERS.—Wednesday, December 14, at 7.30 p.m., a Lecture will be delivered in the Mappin Hall, Sheffield, under the auspices of this Association by Dr. Leslie Aitchison, entitled "The Testing of Drop-Forgings." No tickets are required.

THE ROYAL METEOROLOGICAL SOCIETY.—Wednesday, December 14, at 5 p.m., at 49, Cromwell-road, South Kensington. Discussion on "Visibility" opened by Mr. F. J. W. Whipple, followed by Wing Commander M. G. Christie, C.M.G., D.S.O., from the air pilot's point of view; Captain Sir David Wilson-Barker, R.D., R.N.R., from the seaman's point of view. Dr. J. S. Owens will speak on London Fogs.

THE ASSOCIATION OF ENGINEERS-IN-CHARGE.—Wednesday, December 14, at 7.30 p.m., at St. Bride's Institute, Bride-lane, Fleet-street, E.C. 4, a paper will be read by Major W. Gregson, B.Sc.(Eng.), Assoc.M.Inst.C.E., A.M.I.Mech.E., on "Utilisation of Exhaust Gases from Internal-Combustion Engines." Mr. Frank Bailey (past president) in the chair.

THE SOCIETY OF GLASS TECHNOLOGY.—Wednesday, December 14, at 2.45 p.m., in the Chemistry Lecture Theatre, University College, Gower-street, London, W.C. 1. Presentation and discussion of the following papers:—(*a*) "Notes on Pipettes," by Verney Stott, B.A. (*b*) "Measuring Small Variations of Refractive Index throughout Meltings of Optical Glass," by A. J. Dalladay and F. Twyman. (*c*) "On the Annealing of Glassware, and on Annealing without Pyrometers," by F. Twyman.

THE INSTITUTION OF ELECTRICAL ENGINEERS.—Thursday, December 15, at 6 p.m., "Induction-Type Synchronous Motors," by Mr. L. H. A. Carr, Member.

THE NEWCOMEN SOCIETY.—Thursday, December 15, at 5 p.m., in the Large Theatre, King's College, Strand, W.C. 2. Paper by Mr. R. C. S. Walters, B.Sc., Assoc.M.Inst.C.E., Member, on "Greek and Roman Engineering Instruments," illustrated by lantern slides, will be read.

THE ROYAL AERONAUTICAL SOCIETY.—Thursday, December 15, at 5.30 p.m., at the Royal Society of Arts, 18, John-street, Adelphi. Captain F. M. Green, Fellow, will read a paper on "The Development of the Fighting Aeroplane."

THE NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.—Friday, December 16, at 7.30 p.m., in the Lecture Theatre of the Literary and Philosophical Society, Newcastle-upon-Tyne. "Railway Electrification," by Sir Vincent L. Raven, K.B.E.

THE INSTITUTION OF MECHANICAL ENGINEERS.—Friday, December 16, at 6 p.m., papers will be read on: "Conveying and Elevating Machinery," by Mr. Gardiner Mitchell, Member, and "Discharge of Grain Cargoes in the Port of London by Pneumatic Elevators," by Mr. R. E. Knight, M.C., Associate Member.

THE INSTITUTION OF LOCOMOTIVE ENGINEERS: SCOTTISH CENTRE.—Friday, December 16, at 7.30 p.m., in the Societies' Room, Royal Technical College, Glasgow. Paper on "Steel for Locomotive Purposes," by Sir Henry Fowler, K.B.E. (Past-President), chief mechanical engineer, Midland Railway.

JAPANESE TECHNICAL SOCIETIES.—Journals of the Japanese Society of Mechanical Engineers, and of that Society combined with the Society of Naval Engineers, recently received, printed partly in English, contain a long series of articles which point to the high standard of efficiency in the technical side of engineering and naval construction attained by our Japanese friends.

ROYAL INSTITUTION.—The following are the lecture arrangements at the Royal Institution before Easter: Professor J. A. Fleming, six lectures adapted to a juvenile auditory on "Electric Waves and Wireless Telephony," beginning on Thursday, December 29, on "Surface Waves on Liquids," followed by "Waves in Air," "The Telephone," "Electric Oscillations," "Electric Waves," and "Wireless Telephony." On Tuesday afternoons, commencing on January 17, there will be two lectures on "Physiology as Applied to Agriculture," by Dr. F. H. A. Marshall, three by Professor H. H. Turner on "Variable Stars," five by Sir Arthur Keith on "Anthropological Problems of the British Empire," Series I, "Racial Problems in Asia and Australasia," and two by Dr. J. W. Evans on "Earth Movements." On Thursday afternoons, Mr. Seton Gordon will give two lectures on "Mountain Birds of Scotland and Sea Birds and Seals," Sir Napier Shaw two on "Droughts and Floods," Professor A. G. Perkin two on "Dyeing: Ancient and Modern," Professor H. Maxwell Lefroy two on the "Menace of the Insect Pest: The Balance of Life in Relation to Insect Pest Control," Dr. P. Chalmers Mitchell two on "The Cinema as a Zoological Method," and Professor A. M. Hind two on "Landscape Etchers: New and Old." On Saturdays there will be two lectures by Dr. L. de Selincourt on "Humorists of the Seventeenth Century—(1) Sir Thomas Browne, (2) Thomas Fuller," two by Professor E. A. Gardner on "Masterpieces of Greek Sculpture," and six by Sir Ernest Rutherford on "Radioactivity." The first Friday evening discourse will be given on January 20 by Sir James Dewar on "Soap Films and Molecular Forces." Succeeding discourses will probably be given by Viscount Burnham, Sir Francis Younghusband, Professor W. D. Halliburton, Dr. R. S. Watson, Professor J. Joly, Dr. C. M. Wenyon, Professor T. R. Merton, Dr. A. P. Laurie, Professor F. G. Donnan, Mr. A. B. Walkley, Sir Ernest Rutherford and other gentlemen.

FLOATING CRANE FOR COALING VESSELS AT MONTREAL.

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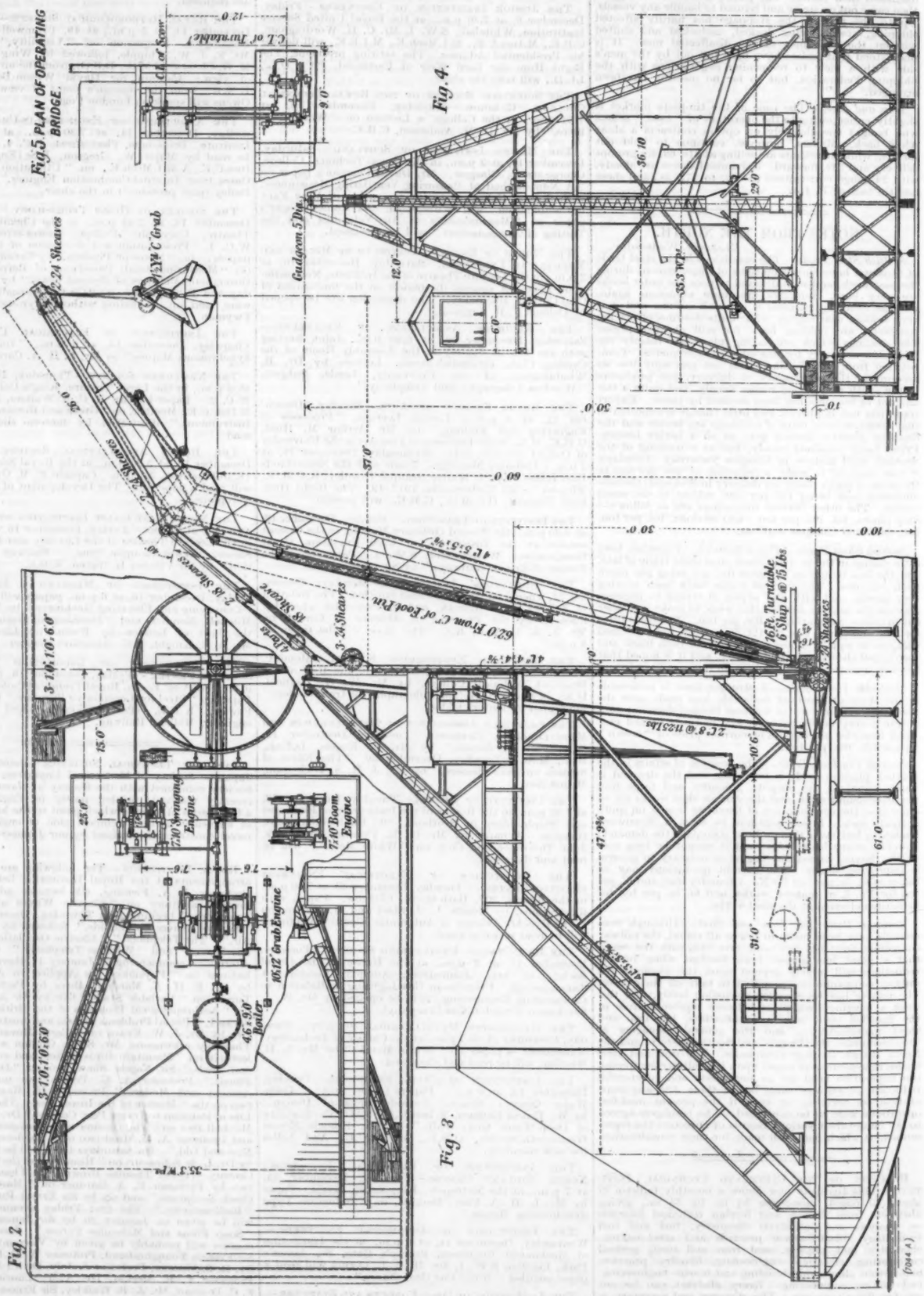
(For Description, see Page 784.)



THE WORKS OF MESSRS. CLARKE'S CRANK AND

(For Description see Page 77

Fig. 4. Large Crank-Shaft Lathe in Turnery.

Fig. 5. Heavy [illegible]achine S

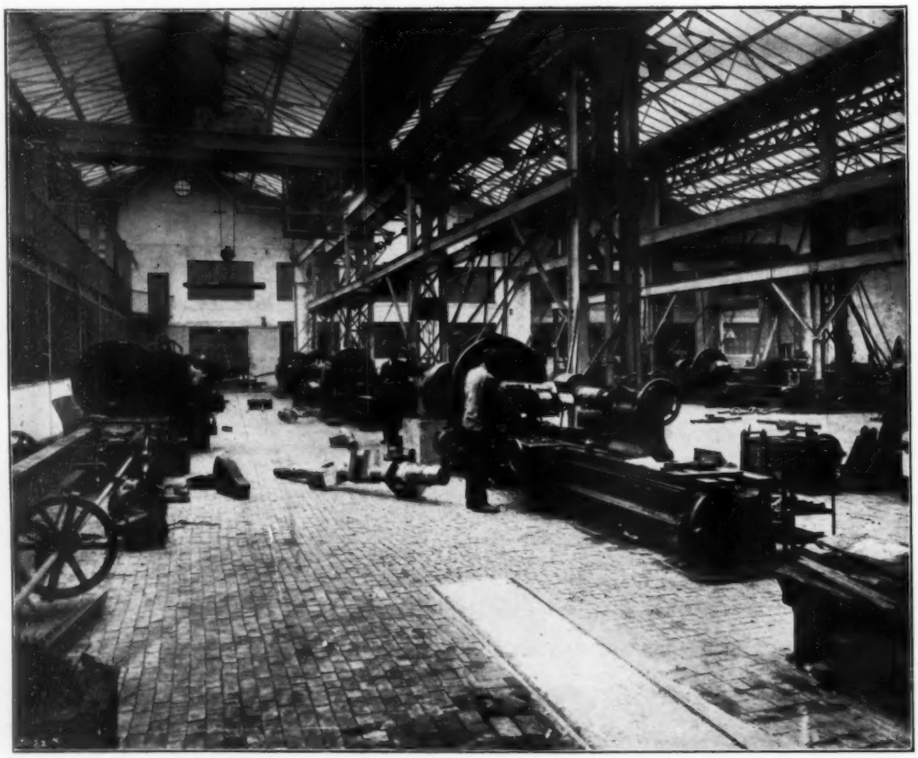


Fig. 7. General View of Turnery.

Fig. 8. Crank-Pin Turning and [illegible]

...K AND FORGE COMPANY, LIMITED, LINCOLN.

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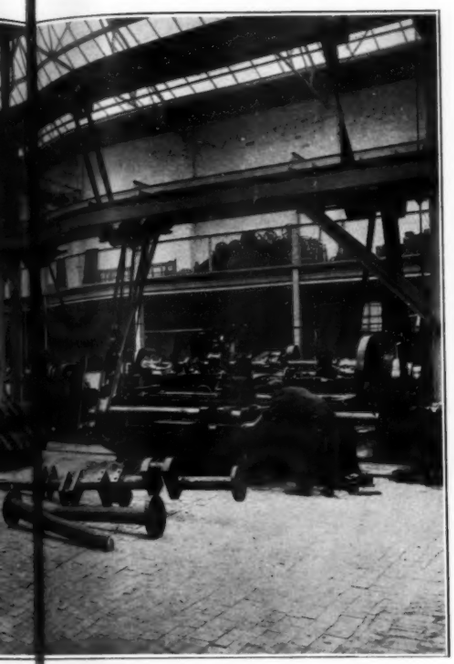


...EAVY ...ACHINE SHOP.

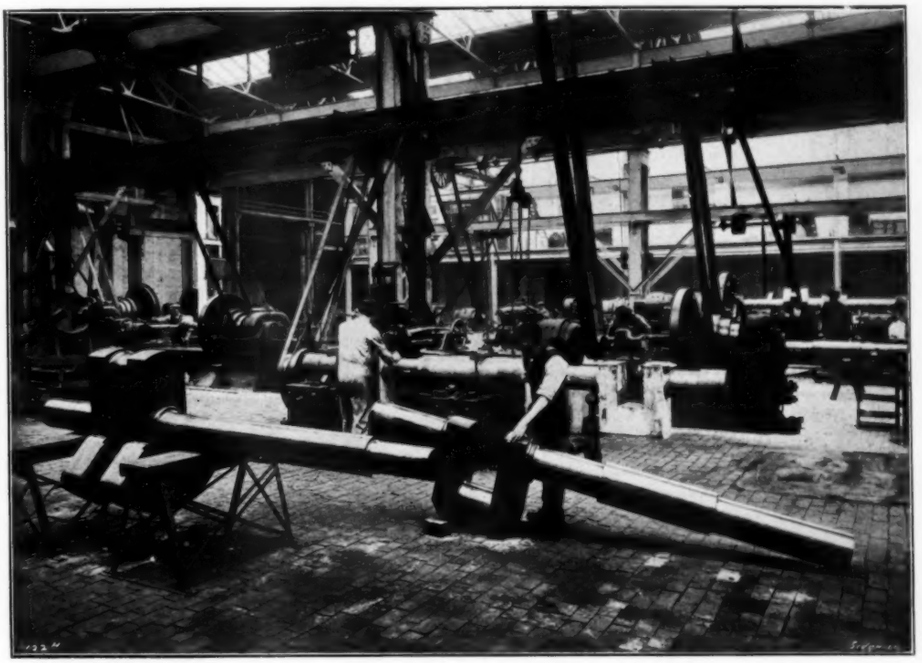
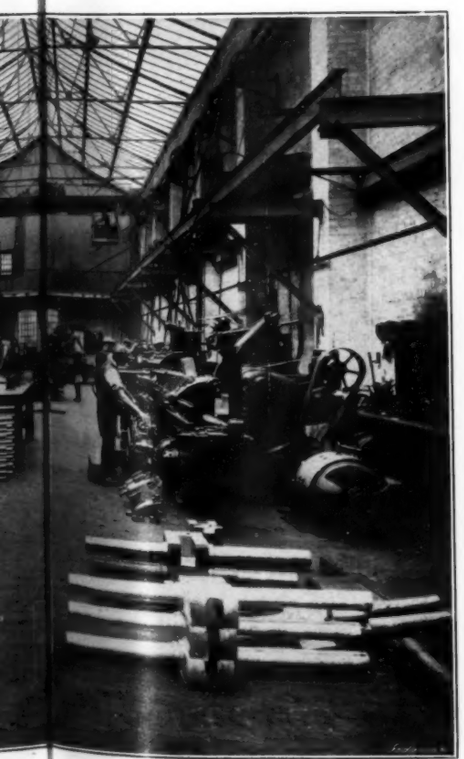


FIG. 6. FINISHING AND INSPECTION BAY.



...TURNING AND GRINDING MACHINES.

FIG. 9. SHOWING NEW SHOPS COMPLETED OVER OLD BUILDING.

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With a Two-Page Plate of the WORKS OF MESSRS. CLARKE'S CRANK AND FORGE COMPANY, LIMITED, LINCOLN.

NOTICES OF MEETINGS.

Notices of Meetings to take place during the present and next week will be found on page 791.

ENGINEERING.

FRIDAY, DECEMBER 9, 1921.

ELECTRIC LOCOMOTIVE DRIVES.

THE design of electric locomotives for main line working has been attacked along two distinct lines of thought. The earlier electrically-propelled vehicles, of comparatively small capacity and power, adopted what was obviously the simplest arrangement with the armature on the axle, or with single-reduction gearing. In spite of limitations of space, and other drawbacks, it has been possible by multiplying the number of axles, to produce very powerful locomotives of this class, which are thus the direct descendants of the comparatively modest tramway or urban railway electric motor vehicle. The type has proved popular in this country where, however, we are at present not very advanced in experience of main line electric traction. The largest developments are to be seen in the United States, where this type of machine has been used to a great extent—probably the largest units being on the Chicago, Milwaukee and St. Paul Railroad, and in use in its recently electrified mountain section.

The other line of thought has tended to make electrical engineers break away rather more from tramway tradition, and combine their ideas with the hardly-won experience of steam locomotive work, with a view to attempting a design which not only secures a freer hand as regards electrical equipment, but is also intended to provide a better type of machine considered from the point of view of a vehicle.

The simplicity of the first class is attractive, but more apparent than real. Moreover, the design suffers from inherent defects which cannot be disregarded. In units of a size such as might be used in this country for freight service these defects might not be very pronounced, and in any case it must be admitted that decisive factors will depend upon the particular service to be dealt with. The chief disadvantages of the direct drives are that the limitations of space in the immediate neighbourhood of the driven axles cramps and complicates the electrical gear, the centre of gravity is undesirably low, and the motor has to work in the dirtiest position it is possible to find on a railroad vehicle of any description. In addition there is always more or less complication to be faced if it should become necessary to unwheel the machine for attention and repairs to the wheels, bogies, &c. That failures, due directly to the motors operating in so exposed a position, are rare, is a matter for congratulation to the electrical industry, and proof of the robustness of the machines developed. The inate love of the average engineer for machinery will, however, make him long for some other arrangement in which the motors might receive better treatment, and will not allow him to rest altogether satisfied with things as they are.

The coupling-rod school, if we may call it so, gets over the difficulties of cramping, and, following approved steam practice, aims at a higher centre of gravity. In this way it has developed a machine which is easier on the permanent way and has better riding characteristics at high speeds. It is somewhat curious that these important reasons for so radical a departure from the small direct unit locomotive idea, seem hardly to have been appreciated at the Engineering Conference in July last, for the view then appeared to be one of astonishment that able Continental engineers should continue to endeavour to develop the coupling-rod drive. Sir Vincent Raven, in his opening note on "Electric Locomotives," held the scales even. It is not so necessary, we take it, in such a task, to make a partisan case, as to review the whole situation as it is known to exist, with a view to encouraging debate. In his reply at the close of the discussion, however, Sir Vincent also appeared to range himself against the coupling-rod school.

Something in the way of a statement from the other side was given in a paper, read before the Franklin Institute last April by Mr. A. W. Gibbs, chief mechanical engineer of the Pennsylvania Railroad system, and now published in that Institution's journal. The paper is rather a welcome change. It does not trouble with "characteristic curves" and the arguments for electricity *versus* steam, which have been so constantly repeated, but concerns itself with mechanical points of high-speed high-power locomotives, steam and electric, with a view to the evolution of one of the latter with the least destructive propensities possible to the road. Mr. Gibbs' information is not altogether of recent origin, but so far as we are aware the detailed facts have not before been published. The investigation to which they belong was commenced many years ago, but still has to be completed. As far as it went, however it afforded sufficient data to influence fundamentally the policy of the Pennsylvania Railroad mechanical department, and for this reason the work is worth the notice of all engineers who wish to pass any opinion on the relative merits of the two schools of design.

It may be remembered that in 1907 a serious accident occurred at Woodlawn, on a curve on the electrified section of the New York Central and Hudson River Railroad to a famous train known as the "White Plains Express." Though we believe never conclusively proved, this accident was, in part at least, generally considered to have been due to the bursting effect at high speed of an electric locomotive of very low centre of gravity (44 in. above the rail level) on a single-spiked track, which for years had stood up to steam working. This accident was instrumental in first attracting serious attention to this point, and as at the time the Pennsylvania Railroad was contemplating electrification in connection with its New York terminus, with the thoroughness so characteristic of that system, before committing itself to accepted designs, a very important piece of experimental work was instituted. A length of track was fitted with special sleepers on each of which was placed, outside the rails, on both curve and tangent, instruments intended to indicate the side thrust on the rail produced by a locomotive at high speed. No absolute interpretation of the blow sustained was secured, the tests being rather of a comparative nature of the effect produced by different types of locomotives.

Each rail was mounted on the sleepers by means of two plates, between which were arranged, parallel to the rail, a number of ¾-in. rollers. Outside each rail there was fixed to the sleeper a casting, which formed an anvil for a hammer or ram, fitted with a hardened ball head, and working in a guide. The butt end of the hammer was in contact with the rail head; and the ball head with a strip of boiler plate on the anvil. The engine on striking the rail sideways caused an enlarged Brinell impression to be made on the test pieces, and these were calibrated by static load tests so that comparative values were established. The experiments being made to obtain a measure of the effect of side thrust caused by the locomotives, the interposition of the rollers was not detrimental, but it must not be forgotten that on a good track the frictional effect of the loaded rail on the sleeper is of great importance, and has considerable influence on the shear on the spikes. It is for this reason that a high-centred locomotive does less damage to a track than would be caused with a low centre of gravity, the load on the outer rail being increased to a much greater extent in the former than in the latter case. For instance, in the Woodlawn accident above referred to, the electric locomotive had a centre of gravity 44 in. above the rail, whereas "Atlantic" (4-4-2) type steam locomotives, with a centre of gravity of 72·7 in. above the rail, had for years run over this road without trouble resulting. It was calculated that at 70 m.p.h. on the curve in question, the load on the outside driver of the steam locomotive was 37,695 lb., and on the electric locomotive 19,950 lb. While the calculated thrust at the outside leading driver was slightly greater for the steam locomotive, the additional weight in that case reduced the shear on the spike to 5,970 lb., while with the electric

machine it was about 9,130 lb. These figures were, of course, based on certain assumptions, and the subsequent Pennsylvania tests are therefore all the more interesting in spite of their obvious limitations.

The steam locomotives selected for trial were of the "American" (4-4-0) passenger type, and the "Atlantic" (4-4-2) type. The electric locomotives were of four designs, as follows: (1) With two four-wheel articulated bogies, with gear drive; (2) two four-wheel articulated bogies with quill drive; (3) 4-4-0 type locomotive with quill drive; (4) two four-wheel pivoted bogies with quill drive. Records for the "American" and "Atlantic" types of steam locomotives showed very similar results with a marked absence of any points of excessive thrust due to bad nosing. On the other hand the electric locomotives of types (1) and (2) revealed the frequent recurrence of extremely heavy side blows on the rails, giving ball impressions on the test pieces five times as deep as the average normal result for the curves, and five times that of the mean for the steam locomotives. When types (1) and (2) were coupled together the record was just as bad. In the case of the locomotive of type (4), curiously enough the records show up rather well, but the fact unfortunately remains that this class became so dangerous on the road, after a certain amount of wear had accumulated, that a third carrying axle was added to each bogie.

The best record for the electric locomotives was made by the 4-4-0 type. The uniformity of the impressions given by this machine was as good as, if not slightly better than, the corresponding steam locomotive, though with the centre of gravity of the former at 55 in. and of the latter at 63 in. above the rail, the shear on the rail fastenings would still have been in favour of the steam locomotive. The steam express locomotive is intended normally to run in one direction. The electric locomotive is, however, commonly expected to run either way indifferently. The 4-4-0 electric machine was therefore tested reversed, and it was found then to give impressions equivalent to a static load of 15,553 lb. maximum, compared with something like 6,700 lb. when running forward. The bogie bolster was then blocked, and the truck merely allowed to swivel. On a repetition of the tests average results equivalent to a static load of 8,010 lb. forwards, and 5,700 lb. reversed, were obtained at high speeds. Parenthetically it may be remarked that these results suggest that the type of tank engine so popular over here, with four coupled drivers and bogie under the footplate and bunker, is really one well adapted to the service in which it has been used, in spite of all official attempts to discredit the design.

It was upon the results of these experiments that the Pennsylvania decision was arrived at, to adopt machines consisting of two 4-4-0 units coupled back to back, the coupling rod drive being chosen in order to secure at high speeds the undoubted advantages of a high centre of gravity. The speeds of the tests it may be remarked were mostly between 70 m.p.h. and 80 m.p.h., but ran in cases up to 95 m.p.h., the higher speeds being taken by the steam locomotives. The tests certainly seem to point to the advantage at high speeds of large wheels with a guiding device, and a high centre of gravity. The coupling-rod drive has been objected to by engineers who would prefer to see pure rotary motion preserved from the motor to the driver. A certain amount of trouble has also been experienced with such drives on the Continent, but it is noteworthy that Mr. Gibbs definitely states that the maintenance of jack-shafts, &c., involves no great difficulty, and the fact remains that the Pennsylvania Railroad locomotives have been working quite satisfactorily since 1910. In steam work it is not the coupling rods which give trouble, and in the electric locomotive it is only a question of parallel rods, and the straight-line motion of a piston and little end do not have to be converted to rotary motion at a big end. These complications are absent.

It is quite possible that in freight working, or, indeed, in such passenger service as is probable in this country for some time, that the quill, or the direct drive may suffice, but there would seem on the other hand to be little doubt that the freedom in electrical design presented by the introduction of the coupling-rod drive, taken with the indisputable advantages of the higher centre of gravity, will ensure this machine a very good share of popularity, especially where easy running at good speeds is sought for on curved roads.

THE AMERICAN MERCANTILE MARINE.

In view of the fact that the United States now possesses a mercantile marine second only in magnitude to that of the United Kingdom, and that some 60 per cent. of the total tonnage is State owned, it is by no means surprising that the American public is deeply concerned as to the future of its ships. The disturbing feature, from the American point of view, is that while roughly two-thirds of the overseas commerce of the United States is still carried by foreign shipping, a large proportion of the American tonnage, probably somewhere about one-third, is idle. No virile nation could, of course, be expected to submit to such a state of affairs without making a strenuous struggle to improve the situation. The struggle will be of particular interest and importance to the shipping community in this country, in that the foreign shipping now carrying the imports and exports of the United States is mainly British, so that the development of the American mercantile marine is likely to deprive British shipowners of some of their business. At the present time, such business is by no means plentiful, and the struggle for it will not therefore be entirely one-sided. The friendship which exists between the two chief contestants, however, is sufficient to ensure that it will be conducted in a friendly spirit.

The importance which is attached to the matter in America is indicated by the fact that three papers read at the meeting of the Society of Naval Architects and Marine Engineers held in New York on November 17 and 18 last, were devoted to the subject of the development of the American merchant navy and to the means to be adopted in order to render competition with foreign ships successful. One of these papers, by Mr. W. A. Dobson, calls attention to the importance to American shipowners, shipbuilders and underwriters of the registration and classification of American vessels being conducted by a purely American organisation. This work is now carried on by the American Bureau of Shipping, and the paper deals with the history, reorganisation and development of this body, giving some particulars of its work during the past five years. In 1917, it will be remembered, the American Bureau formed an alliance with the British Corporation and adopted the rules of that body for the construction of steel vessels. Similar alliances have since been made with the Registro Navale Italiano and with the Imperial Japanese Marine Corporation, and working arrangements have been made by which each society represents the others in its home country. The activities of the American Bureau reached a maximum in 1919, in which year 898 vessels, with an aggregate gross tonnage of 3,030,962, were classed, the Bureau making 1,729 surveys and employing 179 surveyors exclusively for its work. In the following year, the gross tonnage classed declined to 1,918,007 (514 vessels) but the surveys made numbered 4,122. The Bureau, Mr. Dobson remarks, is working in complete harmony with American shipbuilders, and is rapidly gaining the confidence of shipowners and underwriters. He points out, however, that much still remains to be done in strengthening its forces and in making affiliations for the appraisal of damages and for salvage operations.

Another paper, by Rear-Admiral H. H. Rousseau, calls attention to the importance of port facilities in the development of merchant shipping and commerce. He points out that between July 1, 1917, and August 1, 1921, the American merchant marine increased from 1,571 vessels, making 3,640,320 gross tons, to 3,734 vessels aggregating 13,335,072 tons, the increase in numbers equalling 138 per cent. and in tonnage 266 per cent.—figures indicating the extent to which the demand for port facilities has increased during a period of just over four years. Data quoted by Admiral Rousseau show that there are about 30 important seaports in the United States, but that some 75 per cent. of the country's overseas commerce passes through a dozen of them; New York, of course, is easily first in importance and is followed, at some distance, by Philadelphia, New Orleans and Norfolk. There is, he says, considerable competition between the various ports for business and also for funds from the national treasury for the purpose of development, and he suggests that, in future, preference should be given in allocating those funds to the ports which are most interested and most successful in carrying out the national policy that the greater part of American overseas commerce should be carried in American ships.

Admiral Rousseau strongly deprecates the control of ports by railway companies, and quotes from a report by the Board of Engineers for Rivers and Harbours to the effect that the board's investigations show that the charges and practices at railroad terminals at South Atlantic and Gulf ports have exercised an injurious effect upon the commerce of the United States by rendering it impractical for private and municipal terminals to handle through business, thus restricting port growth and development. The ideal system of port control Admiral Rousseau regards as that which has been adopted with conspicuous success in this country, but is comparatively new in the United States, viz., control by an independent port authority. He also expresses the opinion that if this type of organisation were to be generally adopted in America, more would be accomplished for the improvement of the ports, and indirectly for the benefit of the mercantile marine, than would result from any other means. In selecting the membership of the governing boards of such authorities, Admiral Rousseau suggests that the United States should follow the examples of Liverpool, Manchester, London and other British ports and include representatives of shipping, labour, railway, commercial, financial and municipal interests.

The other paper to which we wish to refer is by Mr. W. L. Marvin, and it deals with the methods to be employed to enable American ships to compete successfully with foreign ships, notably, of course, those of Great Britain. The author refers in detail to the factors which have rendered that competition difficult and ineffective in the past, mentioning particularly the higher cost of shipbuilding work in the United States as compared with similar work in Great Britain and the higher wages paid to officers and seamen on American vessels. To show the effect of the latter factor, Mr. Marvin gives the wages cost per month for operating an 8,800-ton deadweight single-screw cargo steamer burning coal, in the mercantile marines of the United States, Great Britain, Japan and Norway. The figures previous to May 1 last would be 5,315 dols., 3,924 dols., 2,869 dols. and 3,378 dols. respectively, the pound being taken as the equivalent of 4·86 dols., the yen as 0·50 dol. and the kroner as 0·26 dol. Since the above-mentioned date, the scales of pay have been reduced in each of the countries considered, and as exact data of the rates in the Japanese and Norwegian merchant services were not available when the paper was written, the author could not usefully compare the labour costs of operation at the present time. Actually he considers that the present cost of wages and maintenance for British and Norwegian ships is about half the corresponding figure for American ships, and as these charges constitute about 15 per cent. of the total working costs, the handicap of the American shipowner will be obvious.

Another drawback hampering the American merchant service referred to by Mr. Marvin is the lack of a world-wide mercantile and maritime organisation such as that of the United Kingdom which, he points out, enables this country to meet the competition of other nations having still lower wages rates. The remedy he suggests is the formation of a similar and equally powerful organisation of American manufacturers, merchants and bankers for the purpose of securing the carriage of a greater proportion of American imports and exports in American ships. To remove the disparity between the working costs of American ships and those of competing nations, the author suggests the institu-

tion of a system of preferential duties or subsidies and subventions. Means, he says, must also be found to offset the national assistance given to ships of competitors, and some form of compensation is also required to cover the increased first cost of American-built ships.

Mr. Marvin is, of course, in complete agreement with the views expressed in Mr. Dobson's paper as to the classification and survey of American shipping by an American organisation, and, in conclusion, he calls attention to the need for American shipowners to develop, as rapidly as possible, a corps of the most efficient seagoing officers in the world. This, we agree, is certainly essential, but its production in a short space of time will be no easy matter. The time element is also a material factor in setting up the world-wide mercantile and maritime organisation above referred to, such organisation as this country possesses having taken very many years to build up. However, we by no means underrate the importance of a determined national effort on the part of the United States to secure for itself a greater share in the world's carrying trade, especially with respect to its own imports and exports. At the same time we must not lose sight of the circumstance that the trade movements likely to follow the present period of depression and stagnation will probably provide sufficient cargoes for the world's merchant shipping without very severe competition.

THE SMITHFIELD SHOW.

THE annual show held by the Smithfield Club at the Agricultural Hall suffers from our point of view from the fact that it follows the Royal Agricultural Show by a comparatively few months, while this year it follows a Public Works, Roads and Transport Exhibition by only a few weeks. This latter show covered, of course, different ground from that represented by the Smithfield Show, but there is of necessity much haulage and transport machinery which is equally at home in either, and a walk round the present exhibition at the Agricultural Hall conveys a general impression of similarity to the earlier show in the stands devoted to traction engines, steam tractors and similar plant. We are well aware that these exhibitions are not held for our benefit, and the showing at both exhibitions of a road locomotive which may be equally of interest to an agriculturist or a road surveyor requires no apology. The condition, however, makes somewhat more difficult our description of the exhibits, since while we do not wish to ignore important material we at the same time do not wish to repeat ourselves too soon. Under the circumstances it would appear allowable to refer to what we may call the heavier exhibits in somewhat general terms.

In making these remarks we do not wish to convey the idea that the part of the exhibition devoted to tractors and similar plant is in any way lacking in interest. There is indeed a very complete and interesting collection of this type of material which makes a fine display, and practically all the makers whose names are so well known in this field are represented. The displays are by no means mere duplicates of those we referred to in our article dealing with the Public Works Exhibition since, although in many cases some of the same machines may be shown, other plant of a more directly agricultural nature has been added. An exhibitor in this class whose display is, we think, entirely different from their earlier one, is Messrs. John Fowler and Co. (Leeds), Limited, of Steam Plough Works, Leeds. This firm show examples of their well-known cable ploughing engine and of their motor plough, but the exhibit which most attracted our attention was a large compound steam road locomotive with twin solid rubber tyres on the driving wheels. This engine well illustrates the extent to which the fitting of rubber tyres is now being carried. Another large and striking machine of this class is shown by Messrs. Charles Burrell and Sons, of Thetford, Norfolk.

The majority of the well-known traction engine and tractor builders show other machines in addition, as, for instance, Messrs. Ruston and Hornsby, of Lincoln, with threshing machines, binders, &c.; Messrs. Robey and Co., of Lincoln, with an oil engine and a trailer; Messrs. Ransomes, Sims and Jefferies, of Ipswich, with a threshing machine, potato digger, &c.; and Messrs. Marshall, Sons and Co., of Gainsborough, with a machine for pulling flax. In this machine the pulling of the growing flax without injury to the fibre is done by a succession of rotary steel combs carried on two endless chains. The chains travel on steel rollers which run on steel angle rails fixed on each side of the puller. At the back end of the puller the rails are curved to serve as cams. The opening out of the comb mechanism in travelling along the cams produces a lifting or backward movement and brings the comb cleaners into action. In this way the combs are kept clean and the pulled flax is not carried over the upper structure of the machine. The combs come in contact with the crop on the underside of the machine, travelling backward as the machine is drawn forward either by horses or a tractor. This contra-action reduces any risk of deseeding which might possibly occur with an over-ripe crop. The action of the machine is said to be so perfect that practically all weeds are left standing in the soil.

The agricultural tractor is not very heavily represented, but several of the well-known makes are on view, and it is of interest to note that a number of these have been reduced in price to a figure in the neighbourhood of 300*l*. This is for standard tractors and not for special light or cheaply built machines. Firms to which this remark applies are, for instance, the Saunderson Tractor and Implement Company, of Bedford, and the Austin Motor Company, Limited, of Northfield, Birmingham. An interesting small tractor on which the driver does not ride was shown by Messrs. Price, Service and Co. of 209, Balham High-road, S.W. 17. This machine, which has a 4½-h.p. engine, is listed at 165*l*. This tractor should be of considerable interest to the market gardener, nurseryman and small holder. It has a water-cooled engine running at 1,200 r.p.m., and the machine is geared to travel from ¼ mile to 3½ miles an hour on the road, and 2½ miles an hour on the field. The complete weight is 9 cwt. Either a plough or a cultivator can be fixed to the machine, and the usual pulley is fitted for machinery driving. It can turn an 8-in. furrow up to 6-in. deep in two-horse land, an eighth of an acre has been ploughed 6 in. deep in an hour.

We have referred to this "Service" tractor in the past, but a recent addition which we have not seen before is a spraying outfit for limewashing, spraying fruit trees, &c. This addition consists of a 300-gallon tank, on its own wheels, to carry the mixture, a spraying pump driven by the engine which may be in use when the tractor is travelling, spraying nozzles, &c. The tank is towed by the tractor, and the whole arrangement moves together. The outfit should be of much service to large fruit growers. Mention of it raises the whole question of the spraying of fruit trees and crops, and in this connection it is interesting to note what a very large number of different makers of sprayers of the portable type are on view at the Agricultural Hall. These in general, of course, are furnished with a hand pump which generates an air pressure above the surface of the spraying mixture in a closed vessel. The increase in the number of makes of this type of article suggests a growing appreciation in this country of the value of spraying in keeping down fungoid and insect pests. Quite a small acquaintance with the state of some British orchards will, however, make it clear that much still remains to be done.

One of the engineering items which is shown in very large numbers is the small internal-combustion engine. This is to be seen either of the fixed type or mounted on wheels for moving about and independent for driving farm or other machinery, or coupled to pumps, electric lighting dynamos, &c. This class of engine is now made in very large quantities, and we would not like to be required to say how many different makes, home and foreign, are available in the British market. As we have more than once had occasion to remark the finish of the British machines is better than that of those which come from across the Atlantic. A better-finished machine will in general be easier to keep clean, while its appearance suggests better vital workmanship, but it is possible that home makers have in the past lost business by putting forward a more expensive machine than the market will buy. This condition would, however, seem to be passing since although there would appear to be no falling-off in the quality of the British engines they are now offered at prices which compare very favourably with those of foreign make.

As an example of a moderate price for a good article we may refer to the 1½-h.p. Petter Junior stationary type oil engine shown by Messrs. Petters, Limited, of Yeovil. This is not the cheapest engine of this size in the show, but it would be difficult to beat it for value. It is interesting to note that this 1½-h.p. engine is a new model. We think we are correct in saying that up to recently the smallest engine of this class built by Messrs. Petter was of 2½ h.p., but the large number of engines of smaller capacity which have appeared in the market suggest that there is a demand for these tiny machines. Another series of beautifully made engines is shown by Messrs. Crossley Brothers, Limited, of Openshaw, Manchester. These are of the horizontal type, a point they have in common with many of the small American engines. The engines are built with a jacket water hopper and are fitted with high-tension magneto and ignition. A similar line of engines is also built with jacketted cylinders arranged for working in conjunction with a water tank. Another well-made small engine is shown by Messrs. Agricultural and General Engineers, Limited, of Central House, Kingsway, W.C. 2. This forms part of the "Bull" electric lighting set. The engine is built by Messrs. Peter Brotherhood, Limited, of Peterborough, and the dynamo by the A.G.E. Electric Motors, Limited, of Stowmarket. The set is neatly arranged on a single bedplate and the switchboard is carried above the generator. The main bearings of the engine are of the "Skefko" ball bearing type and the big-end is fitted with a roller bearing. The engine is rated for a continuous output of 2 b.h.p. to 2½ b.h.p.

An interesting machine which was referred to in our columns, when in its early form a few years ago, but which has now been developed, and of which the manufacture has been taken up in this country, is shown by the Land Drainage Excavation Company, Limited, of Westlode-street, Spalding. This is a land drainage excavator intended for cutting trenches for the laying of agricultural and other drain pipes. The machine, which is known as the "Revolt" consists essentially of an elevator carried above a spudded wheel. At the front and lower end of the elevator there is a U-shaped cutter which scoops up a continuous layer of soil, which enters the elevator and is discharged to a chute at the top which delivers it to one side clear of the trench being cut. An adjustable shoe in front of the cutter regulates the thickness of cut. The elevator is driven by the spudded wheel, which grips the ground and rotates as the machine is drawn forward. The excavator is built in two sizes, one cutting a drain 8 in. wide and up to a depth of 3 ft. 6 in. Each cut may be from 1 in. to 8 in. thick, depending on the nature of the material being dealt with. The larger machine cuts a drain 14 in. wide up to a depth of 3 ft., and is intended primarily for irrigation work in tropical and semi-tropical climates. The smaller machine is intended for farm drainage at home. In both cases the machine is intended to be drawn by a tractor or horses, and an attendant is required behind to steer the excavator until the partly-formed trench gives practically automatic steering. The smaller machine requires from two to four horses, depending on the nature of the land.

THE PARIS AERONAUTICAL EXHIBITION, 1921.

By Major R. H. MAYO, O.B.E., M.A., A.M.I.C.E., F.R.Aë.S.

THE present unsettled state of the aeronautical industry is clearly reflected in the Seventh Aeronautical Salon at the Grand Palais, Paris. Many of the exhibits are of very considerable interest, and it is obvious that in several directions progress has been made since the last Salon in December, 1919, but taken as a whole the Salon seems to

indicate a lack of initiative and a lack of co-ordination of ideas. The designs do not appear to have been produced to meet any specific demand, they seem to be the tentative suggestions of individual designers to fulfil certain purposes which they suppose to be the requirements of the operating concerns. But the operators do not appear to have come to any conclusions as to what they really require, and they are content to experiment with what the designers choose to give them. All this is the natural outcome of the conditions under which the aeronautical industry has been kept alive since the end of the war, and while the industry remains dependent on Government subsidies progress in design is likely to be slow.

There are two markets for aircraft which can be considered seriously—the military market and the commercial transport market—and of these the former is still of vastly greater importance to manufacturers as a whole than the latter. It is not that the governments of the great Powers engaged in the late war are giving extensive orders all round for military machines, but rather that the smaller Powers and the Powers whose air fleets were not developed during the war are anxious to make up for lost time, and are now equipping themselves with the types used by the great Powers in the later stages of the war. Thus, the main outlet for the energies of the aircraft constructor is not for new designs but for designs of proved military effectiveness, and although a large proportion of the machines exhibited at the Salon are intended for purely military purposes, there is very little in this class which is essentially new.

The position in regard to commercial aircraft is different; there is a demand for radically new types, but owing to the dependence of the operating companies on Government subsidies, this demand does not find adequate expression. There will not be an insistent demand for essentially improved types while the operating companies are able to draw the full subsidies on almost any type of machine however unsuitable it may be for its work. It is not surprising to find, therefore, that there is very little progress to be observed in the general design of aircraft or aircraft engines—as regards safety, reliability and economy the machines show no real advance over those seen at the Grand Palais nearly two years ago.

The exhibits at the Salon are almost exclusively French. This is due partly to the fact that British and other foreign aircraft firms are compelled to avoid all unnecessary expenditure at the present time, and partly to the fact that under the present national subsidy schemes there is little chance of a foreign firm being able to sell its products in France. The only foreign aeroplanes shown are the Italian Ansaldo and Ricci machines, and the Dutch K.L.M. designed by Fokker; there is also a Vickers' Vimy with Napier "Lion" engines, but this is exhibited by the French Grands Express Aériens, who are to build machines of this type. On the other hand the Bristol Aeroplane Company, Limited, shows the "Jupiter" engine, which is one of the most interesting exhibits in the Salon; further reference will be made to this engine later. These, however, are the only foreign exhibits of any importance, and the Salon must therefore be regarded as showing the trend of French design only.

The aircraft shown are almost exclusively intended for flying over land; there is one amphibian—an F.B.A. flying boat with a retractable land undercarriage—and one single-seater flying boat, but the French designers on the whole have concentrated their attention on the land machine. The flying boat is naturally of less importance to France than to Great Britain, but in point of fact practically nothing has been done up to the present in any country to develop commercially this most important type of aircraft. Judging by the Salon, the French airship may be said to be dead. Two airship models are shown, one of the well known Astra Torres semi-rigid type, and the other of a vacuum-chamber airship which need not be taken seriously.

The aeroplanes shown vary in size from baby single-seaters to multi-engined passenger carriers with stated capacities up to 20 passengers, but a noticeable feature is that the majority of the commercial machines are of strictly moderate dimensions. There is only one machine which can be considered to be large according to present-day standards, viz., the Farman B.N. 4 bomber, but as this is a purely military machine, built to 1918 specifications, it is of little present-day interest. The small single or two-seater private touring machine is to be seen at the Salon, but the absence of a real market has clearly placed this type for the time being in a position of no importance.

The most important and striking feature of the Salon is the marked concentration of the French designers on the multi-engined machine. Of the 13 passenger-carrying commercial machines shown, seven are single-engined and six multi-engined, but these figures do not fairly represent the tendency, since the multi-engined machines are all the latest productions of the respective firms, while nearly all the single-engined machines shown have been in service for considerable periods. The single-engined machine has in fact been tried out in France and found to be unsuitable for commercial use. There is, of course, much to be said on either side, but there are two essential reasons for the present concentration of the French designers on the multi-engined machine, viz.: (1) It is hoped to obtain safety in numbers; the more engines fitted, the less will the failure of one of them matter; and (2) there is no suitable French engine of 400 h.p. to 500 h.p. and of proved reliability which would enable a single-engined machine to carry a reasonable load of passengers or freight. Thus the multi-engined machines vary from the Caudron with three 140-h.p. Hispano-Suiza engines to the Blériot-Spad with four 300-h.p. Hispano-Suizas. The Caudron would have been a better machine with one reliable engine of 400 h.p., while in the case of the Spad a couple of such 400-h.p. engines would have done very nearly, if not quite, as much as the ungeared Hispanos in tandem can hope to do. The Bréguet Léviathan, with its group of four Bréguet engines geared together to drive a single propeller, which has been written and talked of for so long, is shown in skeleton form with the engines in position. The system has a good deal to commend it, but the time and effort spent in perfecting the gears and automatic clutches would perhaps have been better spent in producing a single powerful engine designed essentially for reliability. It may be remarked that the tendency in British design is in sharp contrast to that in French design; the fact that they have had at their disposal a reliable engine of 450 h.p. has enabled British designers to concentrate on single-engined, or at the most two-engined machines, and thus cut out the many sources of trouble inherent to multiple-engine types.

Another very pronounced tendency noticeable at the Salon is the way in which metal construction has come into favour. A number of French designers seem to have been convinced that, at any rate for the larger sizes of aeroplane, metal construction is superior to the old established wood construction. They have, however, concentrated on the use of Duralumin, no doubt owing to France's favourable position in regard to the supply of aluminium, and there is no example of modern steel construction to be seen at the Salon. The construction usually employed may be described as of the Zeppelin type; in all cases the construction is of a very elaborate kind, involving heavy manufacturing costs. As far as initial cost is concerned, machines built on these lines must necessarily be far more expensive than machines of wood construction, unless the manufacturer is able to produce in very large numbers. In actual service, Duralumin-built machines would normally have a longer life than would wood-built machines, but it is extremely doubtful whether, at the present stage of development of the aeroplane, it is sound policy to produce a more durable machine if this involves much greater initial cost.

It is disappointing to find so little fundamental improvement in constructional design generally. There is only one machine in which any real effort has been made to reduce the number of parts employed and lower the cost of construction; this machine is the Levasseur touring machine, in which a novel method of construction employing multi-ply wood beams is introduced. The designer of this machine has taken a step in the right direction by reducing the number of parts, especially as regards costly metal fittings.

The designers, as usual, display lack of experience in the field, and no serious attempt has been made to eliminate the difficulties which embarrass those responsible for the upkeep of machines. In the majority of machines, the engines are as inaccessible as ever, no effort is made to ensure that parts likely to be damaged in a bad landing can be easily detached and replaced, and the fuselage is so constructed that damage to one or two members, which may easily arise from a slight accident, will necessitate the complete dismantling and perhaps the scrapping of the whole fuselage. There is, however, a general improvement in detail design and finish; as an example, the use of rolled streamline wires instead of piano wires or spliced cables may be taken.

This aspect of the Salon is fully dealt with later, and it will be seen that there is very little that is new aerodynamically. There is, perhaps, an all round improvement as regards cleanness of design, but the machines shown are not of any particular aerodynamic interest. There is no tendency towards increasing the safety of flying by reducing the landing speed; designers seem to be quite satisfied that landing speeds which were considered safe enough for military machines in the later stages of the war, are safe enough for civil flying. The general public, however, will never take seriously to flying until it is satisfied that the fundamental cause of danger in flying, viz., high landing speed has been eliminated. A few of the machines—M. Herbemont's four-engined Spad, for example—are beautifully designed as regards the reduction of head resistance, and they should be capable of high speeds, but a reduction in landing speed, even to the pre-war standard, would add enormously to the safety of such machines and the reduction of maximum speed involved would not be commercially serious.

Another disappointment is the fact that there is very little improvement in the standard of undercarriage design. Nearly all under-carriages are of the recognised type employing rubber cord as the only means of absorbing the shock of landing. In some cases the vertical travel allowed for the wheels is absurdly small, so that unless a perfect landing is made, the shock is taken direct to the structure of the machine. Apart from the fact that no adequate provision for shock absorbing is made, one or two under-carriage designs are fairly good. In the case of the Henri Potez type "X" three-engined passenger carrying machine, for instance, there is a two-wheel under-carriage under each of the side engines and another two-wheel under-carriage under the forward engine. This enables the wheels of the side under-carriages to be fitted with brakes, and this fact, combined with the wide track of the under-carriage as a whole, will enable the machine to pull up comparatively quickly after landing. There is nothing in the Salon, however, in the way of undercarriages which shows any fundamental advance. There is no under-carriage, for instance, which would enable a machine to make a pancake landing from a height of more than 3 ft. or 4 ft. without doing damage to the machine. It is true that such landings are not systematically made by pilots of average ability, but the fear of the consequences arising from such a landing often induces a pilot to land unnecessarily fast, especially under trying circumstances such as when negotiating a forced landing or a landing in fog.

The inadequacy of the provision for the navigation of the machines is in some cases astonishing. In most of the single-engined machines the pilot is placed behind the passengers' cabin, and in such a position that he can see nothing forward, while his lateral view is generally confined to one side on account of the width of the fuselage. In some of the multi-engined machines, such as the four-engined Spad and the three-engined Latécoère, the pilot is better placed in the forward part of the fuselage, but owing to the large dimensions of the fuselage he has very little chance of navigating accurately except by the aid of a special navigator. In the case of the three-engined Potez machine, the position of the pilot is such that he can see practically nothing

forward while the engine nacelles on either side entirely spoil his lateral view. The position of the pilot in this machine is highly dangerous, his view being entirely inadequate both as regards seeing obstructions when approaching the ground to land and as regards seeing other machines in the air. The Potez machine is by no means the only offender in this direction.

There is, however, one very interesting exhibit which shows that the extremely important question of providing the pilot of a passenger-carrying machine with adequate means of navigating is not being altogether neglected in France. This exhibit consists of a model of the nose portion of the four-engined Spad machine, and it shows the arrangement of the instruments and equipment to be used by the navigator who is stationed in this portion of the machine. He is provided with two windows in the bottom of the cockpit, one looking vertically downwards and the other forward, through which he can obtain a good view of a fairly broad stretch of country beneath and in front of him; he is provided with a compass, and also with a Le Prieur "Navigraphe," which assists him in determining the direction and force of the wind. The cockpit is also fitted up with a wireless telephone set enabling him to keep in touch with ground stations. The navigator is so placed that he can communicate directly with the pilot, who is just behind him. It is understood that the Spad machine will be thus fitted up before it comes into service. This navigator's cockpit has been arranged by M. P. Aujames.

(To be continued.)

NOTES.

THE RECOVERY OF UNBURNED BOILER FUEL.

AN interesting report has been issued by the United States Bureau of Mines dealing with research work for the recovery of unburned fuel from boiler furnace refuse, a work which, it is said, presents interesting possibilities, since 24 per cent. of America's total production of bituminous coal is used in industrial power plants. The expediency of recovering such unburned fuel depends upon the original cost of the primary fuel used, and this having been low in the United States in the pre-war period, little progress has been made there in the direction of recovering the non-consumed portion. In the United States, moreover, the use of mechanical stokers, it is further reported, enables low-priced screenings, having a high ash content, to be utilised; consequently the actual loss in money represented by even a relatively high proportion of combustible material remaining in the screenings is not considered a very great one. The washing and separating plant briefly described in the report is generally of the usual type for apparatus of this class, and the cost of its continuous operation should not exceed 75 cents per ton of fuel recovered. The report gives the results of two of the washing tests made; one test was made using ¾-in. mesh screenings from the boiler furnace refuse, the other being made on the oversize, crushed to pass a ½-in. round-hole screen. The total combined yield in washed fuel was 20 per cent. of the gross weight of refuse treated. The washed fuel had an ash content of 25·5 per cent. and an average calorific value of 9,754 B.Th.U. The heating value of the dry screenings ordinarily fired at the plant is about 10,000 B.Th.U. to 11,000 B.Th.U., and the ash content 18 per cent. to 22 per cent. The yield of the plant is 1 ton of fuel from every 5 tons of refuse handled. A one-table plant which would handle 6 tons to 8 tons of raw coal per hour would treat 5 tons per hour of boiler furnace refuse, and by continuous operation 120 tons of refuse per 24 hours. The working of the installation would require only a part of the time of one man, and in most cases the freight charges on coal purchased in place of the recoverable unburned fuel would be more than sufficient to cover the cost of operation.

THE PORT OF SHANGHAI.

Recent papers from the Far East contain accounts of a dinner given at the Astor House Hotel, in Shanghai, on October 17, which may well prove to be a turning point in the history of that city as a shipping port. The dinner was given to welcome the Committee of Consulting Engineers who are to investigate the possibilities of improving Shanghai Harbour. H. E. Hsu Yuan, Special Commissioner of Foreign Affairs, presided, and he was supported by the members of the Consular Body, representatives of the Chambers of Commerce, Chinese and foreign officials and others interested in the great business of Shanghai. The committee consists of Mr. F. Palmer, consulting engineer to the Port of London Authority; Major-General Black, of the United States Army Engineers; M. Perrier, Ingenieur en Chef du Corps des Ponts et Chaussees, who for twenty years has been connected with the Suez Canal; Mr. Hornell, of Sweden; Dr. Hiroi, from Japan; and Mr. Ott de Vries, of the Dutch East Indies, who have all had distinguished careers as hydraulic engineers. With them is associated Mr. von Heidenstam, who for eleven years has been in charge of the harbour works under the Whangpoo Conservancy Board. The history of the port of Shanghai began seventy-eight years ago with the signing of the Treaty of Nanking, which led to the opening of the treaty ports of China. To-day Shanghai may be regarded as the combined Liverpool and Manchester of the Far East, and in matter of tonnage she ranks about tenth or twelfth among the ports of the world. Situated, however, as it is some miles up the Huangpu which flows into the Yangtsze at Woosung, Shanghai cannot yet berth many vessels of large size, and much transhipment has still to be done. With a population exceeding a million and a half, of whom 26,000 are foreigners, the city does an immense trade. The total tonnage entered and cleared last year was 22,500,000 tons, of which 37 per cent. was British, 27½ per cent. Japanese, 18½ per cent. Chinese, 11½ per cent. American, and 2½ per cent. French, the value of the trade of the port under the cognisance of the Maritime Customs amounting to 841,000,000 taels. Beside this there was a large tonnage of steamers under the control of the native Customs, while 58,000 junks were entered and cleared from the port.

BANKRUPTCY IN THE ENGINEERING TRADE.

The report by the Board of Trade recording the statistics of bankruptcy shows, as might have been anticipated, that there was a very large increase in 1920 as compared with the war years. Then, all factories were as actively engaged as possible, and there was sufficient money in the country to maintain all other industries and trades. But, with the cessation of war and the decrease in the value of money and other causes, there was a sharp decline in commercial and industrial prosperity, with the result that the number of failures jumped to 2,016 in 1920, the liabilities aggregating 6,853,308*l.* This latter figure shows a much larger increase than that of the number of failures. The liabilities, in fact, are as great as in the three years 1917–19 collectively. An interesting point is that even last year those trades which are engaged in the supply of what may be termed luxuries have had a more fortunate experience, and even others which are concerned with the ordinary supplies of necessities have not experienced the same adverse circumstances. For instance, in the case of lace manufacturers and merchants there is a decrease in bankruptcy returns. In drapers and haberdashers there is not by any means the same proportionate increase as in the aggregate. This also applies to butchers and grocers, while in the case of provision merchants there is an actual decrease. It is gratifying to note that, notwithstanding the enormous extent of the engineering and metallurgical industries, the liabilities due to bankruptcy constitute only 7 per cent. of the total for the whole of Great Britain. The total involved is nearly half a million, or, to be exact, 471,007*l.*, whereas the best result during the war years was in 1918, when the liabilities only totalled 72,663*l.*, or 5½ per cent. of the total liability of bankruptcies for Great Britain. In the case of the engineers and founders there have been 14 bankruptcies, involving 97,380*l.* liabilities, while in miscellaneous metal workers the respective figures were 81 and 273,687*l.* Shipowners and shipbuilders are separately classed, and here there were only two bankruptcies last year, involving 42,855*l.* liabilities. This last figure is much greater than in the war years, when the highest was under 3,000*l.* and the average was 1,700*l.* We hope that the current year will not show any material advance, although the prospects are certainly not favourable to the realisation of this hope.

CHILIAN RAILWAY ELECTRIFICATION.

The total mileage of the railroads of Chili amounts to 5,200, of which about 30 per cent. is privately owned for mining and industrial purposes. The remainder may be divided into two main classes consisting of broad-gauge and narrow-gauge track respectively. The broad-gauge lines extend south from Valparaiso by way of Santiago to Puerto Montt, with numerous branches, while the narrow-gauge lines include most of the northern roads and a few branch lines in the south. The necessity for electrifying the broad-gauge lines, especially the Valparaiso–Santiago section and a branch line from Las Vegas to Los Andes, became very apparent during the war, since the traffic on these sections was rapidly approaching their full capacities. Moreover, fuel costs were excessive, and ample water power was available for all possible requirements. As a result of the findings of a Commission appointed in 1918, it was therefore decided to electrify immediately the two sections above referred to, and the contract for the whole of the work has recently been awarded to the Westinghouse Electric and Manufacturing Company, of East Pittsburg, Pa., U.S.A., as briefly announced on page 550 *ante*. The Valparaiso–Santiago line is 116 miles in length, and the branch from Las Vegas to Los Andes has a length of 28 miles; Los Andes, it may be mentioned, is the terminus of the Transandine Railway, which is a narrow-gauge line. The lines to be electrified are of 5 ft. 6 in. gauge, and the maximum gradient to be encountered is one of 2·25 per cent.; there are, however, a relatively large number of curves, the maximum being 10 deg. The 3,000-volt direct-current system has been adopted for the working of the lines, and power will be generated at the Maitines hydro-electric power station of the Chilian Electric Tramway and Light Company, Limited. This station will contain three 8,125 k.v.a. three-phase 50-cycle generators, and the power from it will be transmitted at 110,000 volts over a distance of 37 miles to Santiago, where the line connects with the system fed by the Florida hydro-electric power station and the Mapocho steam station. The power will be distributed by five sub-stations, each containing two 2,000 kw. motor generator sets, and each set comprising a 2,800-h.p. motor driving two 1,000 kw. 1,500-volt direct-current generators connected in series. The traffic will be worked by electric locomotives, 39 of which are required for the two sections first to be taken in hand. These include six locomotives for express passenger service, 11 for local passenger service, 15 for freight service and 7 for switching work. The express passenger engines, which will be of the 2-6-0-0-6-2 type, will have an overall length of 58 ft. 6 in., with a total weight of 127 tons. Each will be fitted with six motors developing an aggregate horse-power of 2,250, which will give a maximum speed of 62½ m.p.h. The wheel arrangement of the freight locomotives will be of the 0-6-0-0-6-0 order, and these engines will also be fitted with six motors giving a total horse-power of 1,680 and a maximum speed of 40 m.p.h. The weight of the freight engines will be 113 tons and their overall length 49 ft. 10 in. Both the express passenger and freight engines will be equipped with the Westinghouse system of regenerative braking, but this feature will not be included on the local passenger engines, since the conditions under which these engines will operate render it unnecessary. The Westinghouse Electric and Manufacturing Company, to whom we are indebted for the further particulars we are now able to publish, inform us that the contract, which amounts to 7,000,000 dols., represents the largest single order for railway electrification equipment ever received in the United States.

NEW RAILWAY WORKSHOPS IN NIGERIA.—Messrs. Sir William Arrol and Co., Limited, state that they have obtained from the Crown Agents of the Colonies the order for the new railway workshops at Enugu (West Africa), for the Nigerian Railways. In addition to the buildings and power station, the order comprises the complete equipment and erection *in situ*.

LITERATURE.

Brassey's Naval and Shipping Annual, 1921–2. Edited by Alexander Richardson and Archibald Hurd. London: William Clowes and Sons, Limited. [Price 25*s.* net.]

The incidence of the Washington Conference adds a special interest to the new volume of "Brassey" which has just been published. The work is now in its thirty-third year, but even not excluding the war period it is doubtful if any issue has appeared at a time more pregnant for good or ill in naval affairs. A review of the volume is not the place in which to deal with the issues before the Conference, but much information bearing on those issues is to be obtained from it, and a study of the naval articles comprising its first section would be of value both to the intelligent general reader and to many of our amateur publicists. In this connection some useful and interesting remarks are made in the volume itself by Mr. L. Cope Cornford, in a chapter entitled "The Criticism of War."

As was the case in the issue of last year a remarkably authoritative collection of contributors has been obtained. Confining attention for a moment to the Naval Section one finds such names as Admiral Sir Reginald Bacon, Rear-Admiral S. S. Hall, Major-General Sir W. S. Brancker, Major-General Sir George Aston and Engineer Vice-Admiral Sir George Goodwin. The contributions of these and other authorities together make up a valuable survey, and consideration of the much-discussed question of the present and future value of the battleship and its relation to the submarine. The possible differences of opinion on this subject, even among experts, is illustrated by the fact that Admiral Bacon concludes by saying that "the newer weapons provided by science and construction, have not in any way pronounced the doom of the capital ship. Nor has modern redistribution of sea power reduced the necessity for our building large ships to protect out world-wide interests." While against this Rear-Admiral Hall's conclusion is that: "The greater distances that for many years appear certain to separate opposing fleets of capital ships, which must always rely upon the gun as their principal weapon, will preclude distant blockade, the sole remaining function left to these fleets in the last war, and by so doing will cause the opportunities for obtaining decisive results by means of gun-fire to diminish still further if not to disappear. This will confine naval warfare to attack and defence of sea communications, and since submarines and aircraft are the most efficient for this, the result will be that the torpedo will be the dominating naval weapon of the future."

It is not possible or necessary here to trace the chains of argument by which these two writers draw wholly different conclusions from the same data. As illustrating, however, the different weight which may be given to the same evidence by different thinkers it is interesting to note Admiral Bacon saying: "Our Grand Fleet steamed in the North Sea a distance equivalent to a triple circumnavigation of the Globe without the loss of a single ship from attack by a submarine. Again, defensive precautions robbed the new weapon of its terrors. It was found merely to exercise certain minor limitations on the free action of the Fleet," which may be compared with Admiral Hall's conclusion that "If a bald statement of percentages of hits to torpedoes fired, or of the numbers of ships sunk by torpedoes in the last war, was any criterion of the future of the torpedo in the next war, one could say at once that the next war will be entirely dominated by under-water weapons." There is no need to question the accuracy of either of these statements. The matter of interest is the respective weight which should be given to each, and the ideas of two important schools could hardly be better put than in the two chapters under consideration. They should be read by all who are interested in the future of the Navy.

These contributions have called for a somewhat lengthy consideration in view of their vital bearing on naval building policy, but they must not be allowed to overshadow other important chapters in the Naval Section of the Annual. Particularly should be mentioned the tactical analysis of the Battle of Jutland, which has been contributed by Lieutenant Commander Ichiro Sato, of the Imperial Japanese Navy. The conclusion is that "There was neither victor not vanquished at Jutland, both sides failing to achieve the end in view." Auxiliary to the main question of battleships *versus* submarine the whole question of aircraft requires close consideration, and an able review of the present conditions and the possibilities is contained in Major-General Brancker's chapter on "Air Power and Sea Power," while "The Problem of Empire Defence" in its broader terms is dealt with by Major-General Sir George Aston. Bearing on the whole of these questions the annual publishes its usual lists, plans and tables of British and foreign warships, ordnance, &c. Before leaving the Naval Section reference should be made to Sir George Goodwin's valuable article on auxiliary machinery. Very much has been written on the main propelling machinery of warships to the comparative neglect of the important question of auxiliaries, and this chapter is timely and useful.

It has been pointed out that the Annual appears at a vital period in naval affairs, and almost the same thing may be said of merchant shipping matters. With commercial shipbuilding apparently working up to something almost like a stoppage, with at least 20 per cent. of the tonnage of the world laid up for lack of occupation and with the worst slump in freights ever known, it is not unfair to say that the conditions affecting the mercantile marine are in their way just as vital as those affecting the navies. The interests concerned will again find very much to interest them, and possibly something to help them, in the new issue of "Brassey's Annual." This subject of the present state of the shipping trade and its reaction on the shipbuilding trade is dealt with very fully, a beginning being made with an important chapter on "The World's Mercantile Marine," by Sir Westcott Abell. The contribution gives an acute analysis of the present trouble which Sir Westcott shows to be due to a very large extent to the increase in capacity of the shipbuilding machine of the world between 1914 and 1920, the capacity practically doubling between these years. The perhaps natural assumption after the war was that all the ships which could be produced were required to make up war losses. Sir Westcott's comment on this point of view is that "If it had been possible in some broad way to control the financial interests involved, it would have been desirable to have cut down the shipbuilding production as suddenly as possible, so as to reduce its output to one-half by somewhere about the beginning to the middle of 1920."

Sir Westcott Abell does not appear to take a very optimistic view of the early future of the shipping and shipbuilding industries, and in this connection much interest will be taken in Sir W. J. Noble's analysis of "The Fall in Freights." By means of curves he shows that freights began to rise during the summer after their rapid and disastrous fall, and on the whole he may be interpreted as taking a somewhat more hopeful view of the situation than does Sir Westcott. The question of oil fuel and the Diesel ship has close bearing on the important questions considered by these authorities and it is of great interest to read Sir Westcott Abell to the effect that "there appears to be no doubt that, in view of the mechanical and economical advantages in the use of oil as fuel, a considerable proportion of the replaced tonnage of the near future will be adapted for the new fuel." This important question receives further consideration in the chapter on "Propelling Machinery in the Mercantile Marine," by Mr. James Richardson, while the basic question of fuel supplies is dealt with by Sir Frederick Black, who writes on "The World's Resources of Petroleum Fuel Oil." Mr. Richardson's chapter, as will be gathered from its title, is not confined to oil fuel machinery, but constitutes a useful survey of the whole field of mercantile ship propulsion. The triple-expansion engine, the steam turbine, mechanical and electrical gearing, the direct-connected Diesel and the geared Diesel and Diesel electrical ship are each referred to and their sphere considered. Even the Föttinger transformer and the speculative internal-combustion turbine are not neglected.

Other valuable chapters are contributed to the "Annual" by Commander Sir Trevor Dawson, Sir Norman Hill and Mr. J. Foster-King. Sir Trevor Dawson writes on "Commercial Airships," and gives a useful and important survey of the whole field. An historical note on what has already been done with passenger-carrying airships is followed by a consideration of the possible routes which might be usefully developed. The important question of the cost of operation is then gone into in some detail, and suggested rates for passengers and mails are given. The possibilities of improvements and development in the future are also dealt with. Sir Trevor, in this chapter, is writing on a subject on which he is an acknowledged authority, and although in the prevailing financial conditions of the world the airship has perforce had to be somewhat neglected, there is no doubt but that better times will see a revival of interest and the translation into practice of some of Sir Trevor's ideas. Sir Norman Hill's contribution deals with "The Importance of Coastal Shipping," the whole question of the coasting service *versus* the railway for traffic between ports being dealt with. Sir Norman Hill is of opinion that coastal shipping and the smaller ports may both ultimately come to a better prosperity through the development of mechanical road transport. The chapter by Mr. J. Foster-King deals with "Japanese Shipbuilding." It is largely narrative, and forms a most interesting account of a striking and important development.

Another chapter which should be mentioned is that on "The Cost of Speed," by Dr. Percy Hillhouse, the new Professor of Naval Architecture at Glasgow University. This article is of a somewhat more technical nature than the majority of the contributions, but gives the general reader an excellent idea of the bearing of the speed factor in shipping economics. Among other useful matter in the "Annual" is an excellent account of Lord Inchcapes' sales of the standard ships and of ex-enemy tonnage, and a consideration of "The Future of German Shipping." The Merchant Shipping Appendix contains a very complete collection of tables and diagrams relating to trade and shipping. This collected and coded information is far from being the least useful feature of the new "Brassey," and should be of much value for purposes of reference. The illustrations scattered throughout the volume are well chosen and printed, and the whole book is a credit to all concerned in its production.

Ypres to Verdun. A Collection of Photographs in the War Areas in France and Flanders. Specially taken by Sir Alexander B. W. Kennedy, LL.D., F.R.S., Past-President of the Institution of Civil Engineers. London: Offices of *Country Life*. [Price 15*s.* net.]

It is a kindly thought of Sir A. B. W. Kennedy to invite the friends of the soldiers who fought on the fields of France and Flanders to enjoy the store of photographs that he collected in that war-scarred territory, as early as possible after the armistice. For military reasons, it was forbidden to use a camera within the lines, and owing to this absence of illustration, many who were compelled to stay at home have doubtless attached quite incongruous ideas to scenes and places, whose names were once as "familiar as household words." The graphic descriptions of able correspondents can give but an inadequate picture of the ruined and desolate country over which hostile armies have crossed and recrossed in the memorable four years, that separated the first battle of Mons from the last. Amid the peaceful surroundings of an English Christmas, such a collection of photographs should prove a welcome gift to many, and accompanied as it is by a heartening and appreciative description of gallantry and heroism, may recall the past and tempt some poor sufferer to "shoulder his crutch and show how fields were won."

Such thumbnail word sketches are the more valuable as the capacity of the photographic plate is severely limited. When the site of a village is preserved only by some rough painted board, planted on a heap of incoherent rubbish, bearing a legend, "This is Givenchy" or "This was Givenchy" the camera and the imagination are alike incapable of summoning up the smitten village that once welcomed the traveller or supported a contented population. In such cases we can only feebly conjure up either the pastoral beauty of the past, or the

suffering of the present. But nevertheless the silent picture conveys a wholesome lesson.

Nor is destruction, either wanton or necessary, the only drawback under which the artistic photographer has to labour in depicting this war country. The topography of the country does not lend itself to decorative effects. There are no picturesque differences of level at least in Flanders, no happy grouping of light and shadow, no marked contrast between meandering streams and sunlit banks, or other contrasts which the photographer selects as aids to an effective picture. The object here is not to delight the eye, but to bring home the wearisome monotony of large expanses, to make the average man understand that greater obstacles have to be overcome than the bravery or the determination of the enemy may offer. "Hill 60," for example, that has for us so many stirring memories that, we have magnified it into a commanding eminence, can hardly be recognised as an elevation, it is little more than a heap of spoil from the cutting of the adjacent railway. If it overlooks a wide country, it is not by reason of its height, but of the flatness of the plain on which it stands. Such flatness implies difficult and imperfect drainage, with a waterlogged soil. The difficulty of attack lies in the sea of viscous mud through which troops have to force their way to reach the object. Perhaps the picture may enable us better to realise the meaning of the phase, "Nine-tenths of the time our men were fighting Nature, and the remainder fighting the Germans." Now the surface is torn up by mine explosions and incessant shell fire, presenting above-ground merely a mass of craters and shell holes, while underground, the soft clay is honeycombed with tunnels and the remains of dugouts.

Neuve Chapelle is another name to conjure with, but there is no village nestling under the shadow of the church which is represented only by a heap of stones, and a crucifix standing in the churchyard with its shaft split by a dud shell. Armentières, and a score of other villages, tell the same tale, but what photograph or what description can do justice to the ruin that marks the country between Bethune and La Bassée, 7 miles distant from each other, and extending miles north and south of that line. Here a thickly populated agricultural community once flourished, and now only a desert exists, "bare of trees, of houses, of crops, of people, growing nothing but shelled craters and barbed wire, with thousands of tons of buried broken shells" beneath its soil. Merville and Estaires present another but equally melancholy picture. They were terribly knocked about by our artillery fire during the enemy occupation. It is some satisfaction, to be able to add that in these towns, as also at Armentières, reconstruction is going on rapidly, and that agricultural operations are once again active on the shell-devastated area. A long time will be required to restore the woods where only groups of bare stems now stand to mark the desolation. These skeleton trunks are among the saddest sights that the photographs record.

Lens affords an instance of the destitution that can be worked on a town of considerable size. Sir Alex. Kennedy compares it to Bedford or Doncaster. It was too large to be wiped out as are the villages, but surveying the scene from high ground "one saw, in 1919, nothing but a waste of bricks and stones and timber, with no semblance of standing buildings. If one had not seen so much appalling destruction in other places, it would have been unbelievable that a town could be as entirely turned into small fragments, as if some gigantic harrow had been drawn across it." Nevertheless, the author adds, that on a re-visit in 1920, he found a considerable amount of rebuilding had been effected, though naturally the greater part of the town was in ruins. As he says in another place, in France they do not wait for trade union permissions, or "skilled" labour, or the sanitary regulations of county councils but go straight ahead and build. It certainly seems the best way of getting houses.

Naturally Vimy Ridge presents a harrowing picture of continuous destruction where gardens and fields are all one mass of ragged chalky shell holes, overgrown with hateful-looking weeds. It is strange in some places that the owners have been able to recognise the particular strip of land which belonged to them before the war, but ploughing is seen to be going on and cultivation was progressing rapidly in a number of places. At Vimy is illustrated in addition to the evidence of wasteful destruction, what the artillery could effect in producing mine craters, and the ingenuity with which the Germans concealed their gun emplacements, but the author's object is generally to depict the country as Moasien has left it, and not to explain military manœuvres or effects.

Rheims was one of the earliest cities to suffer from indiscriminate bombardment, and much indignation was aroused at the time, owing to the firmly held conviction that the destruction of the cathedral was deliberately planned and carried forward as far as possible in spite of all remonstrance. How far the belief was warranted can hardly be settled now, but the evidence of carefully planned destruction in other cathedrals, as for example, that of Saint Quentin, supports the belief. The Germans would be more tempted to destroy a church "which represents in itself and its associations, the faith, and the history, and the life of the country over many centuries and through endless changes and vicissitudes, than a comparatively unknown and less venerated edifice. The careful report on the fabric by Sir A. B. W. Kennedy will be welcomed, for exaggeration has been busy, and the maximum damage inflicted on the most-injured portions have been applied to the whole. The photographs, illustrating the extent of the damage to the east and west ends respectively, show how the Germans used the opportunities that their position gave them. The material damage done to the cathedral, great as it is, sinks into comparative insignificance when it is remembered that of the 14,000 houses in the city, 10,000 were utterly destroyed, only 2,000 were more or less habitable, and the remaining 2,000 may be described as "still standing." Some of the buildings have been so damaged that they present to the engineer strange problems on the strength of materials. This wholesale destruction means that some 100,000 inhabitants were rendered homeless and their property irreparably destroyed.

To pass to Verdun, the end of the line visited, it can be happily recorded, that the city has not suffered to nearly the same extent as Rheims. This is due to the position of the defensive forts, holding the Germans at a distance, so that the shelling had to be effected from positions 4 miles to 8 miles away. Within this zone, however, the villages and woods are destroyed as completely as those in the Somme district. The village of Vaux, which gives its name to the fort where Major Raynal made his heroic defence, has completely disappeared. No sign of its existence remains. The very fragments to which its buildings were reduced are blotted out by the rank vegetation, that hides the scene of so much misery and so much heroism. We may take leave of these sad scenes at the Mort Homme Ridge, where the alternating successes of the contending nations aroused so much enthusiasm, and so great anxiety. The view from this ridge is expressive in its desolation. "In all directions is seen nothing but shell-pocked wastes, the graves of 400,000 Frenchmen and probably of very many more Germans."

BOOKS RECEIVED.

Who's Who in Engineering, 1921–22. Edited by JOHN ED. SEARS, C.B.E., M.A., Assoc.M.Inst.C.E. London: John Ed. Sears. [Price 31s. 6d.]

Columns. A Treatise on the Strength and Design of Compression Members. By E. H. SALMON, D.Sc., Assoc.M.Inst.C.E. London: Henry Frowde and Hodder and Stoughton. [Price 31s. 6d. net.]

Aluminium and its Alloys. Their Properties, Thermal Treatment and Industrial Application. By C. GRARD. Translated by C. M. PHILLIPS and H. W. L. PHILLIPS, B.A., A.I.C. London: Constable and Co., Limited. [Price 17s. 6d. net.]

Regelung der Kraftmaschinen. Berechnung und Konstruktion der Schwemgräder des Massenausgleiche und der Kraftmaschinenregler in elementarer Behandlung. Von Dr. Ing. MAX TOLLE. Third edition. Berlin: Julius Springer. [Price 240 marks, plus 100 per cent.]

Practical Electricity. A Laboratory and Lecture Course for First Year Students of Electrical Engineering, based on the Practical Definitions of the Electrical Units. By W. E. AYRTON, F.R.S., Assoc.M.Inst.C.E. Fourth edition, revised and largely re-written by T. MATHER, Wh.Sch., F.R.S., M.I.E.E. London: Cassell and Co., Limited. [Price 15s. net.]

Proceedings of the Staffordshire Iron and Steel Institute. Vol. XXXV. Session 1919–20. Stourbridge: Mark and Moody, Limited.

Tolley's Complete Income Tax, Excess Profits Duty, Corporation Profits Tax, Super Profits Tax, &c., Chart of Rates, Allowances, &c. Compiled by CHARLES H. TOLLEY, A.C.I.S. Sixth edition. London: Charles H. Tolley. [Price 2s. 6d. net.]

The Motor Boat Manual. Eighth edition. London: Temple Press, Limited. [Price 3s. net.]

Italian Technical Words and Phrases. An English-Italian and Italian-English Dictionary. By E. F. PAVENTA. London: E. Marlborough and Co. [Price 6s. net.]

Marine Diesel and Semi-Diesel Engine Operation and Management, and Control of the Auxiliary Machinery. Embodying the Practice of Vickers, Limited. By Engineer-Lieutenant HAROLD ATKINSON, R.N.V.R. London: E. and F. N. Spon, Limited. [Price 2s. net.]

Proceedings of the Institution of Mechanical Engineers, January to May, 1921. London: Published by the Institution.

Ministry of Munitions and Department of Scientific and Industrial Research. Technical Records of Explosives Supply, 1915–18. No. 3. *Sulphuric Acid Concentration.* London, Manchester, Cardiff and Edinburgh: His Majesty's Stationery Office. [Price 12s. 6d. net.]

Steam Boilers. Edited by TERRELL CROFT. First edition. New York and London: McGraw-Hill Book Company, Inc. [Price 24s. net.]

American Sulphuric Acid Practice. By PHILIP DE WOLF and E. L. LARISON. First edition. New York and London: McGraw-Hill Book Company, Inc. [Price 21s. net.]

Mine Accounting and Cost Principles. By T. O. MCGRATH. First edition. New York and London: McGraw-Hill Book Company, Inc. [Price 24s. net.]

The Working of Steel. Annealing, Heat Treating and Hardening of Carbon and Alloy Steel. By FRED. H. COLVIN and K. A. JUTHE, M.E. First edition. New York and London: McGraw-Hill Book Company, Inc. [Price 18s. net.]

Railroad Shop Practice, Methods and Tools. By FRED. A. STANLEY. First edition. New York and London: McGraw-Hill Book Company, Inc. [Price 24s. net.]

The Design of Highway Bridges of Steel, Timber and Concrete. By MILO S. KETCHUM, C.E., M.Am.Soc.C.E. Second edition. Re-written. New York and London: McGraw-Hill Book Company, Inc. [Price 36s. net.]

An Introduction to Physics. For Technical Students. By P. J. HALEB, M.B.E., B.Sc., M.Am.Soc.C.E., and A. H. STUART, B.Sc., F.R.A.S. London: The Library Press, Limited. [Price 4s. 6d. net.]

The Book of the Ford Electrical Equipment. By R. T. NICHOLSON, M.A. London: Temple Press, Limited. [Price 3s. net.]

Department of Scientific and Industrial Research. Technical Paper No. 4. *The Carbonisation of Peat in Vertical Gas Retorts.* London: His Majesty's Stationery Office. [Price 6d. net.]

State of Illinois. Department of Registration and Education. Division of the State Water Survey. Bulletin No. 16. *Chemical and Biological Survey of the Waters of Illinois. Report for Years 1918 and 1919.* Urbana, Illinois: State Water Survey Division.

Electric Lighting in Factories and Workshops. By LEON GASTER and J. S. DOW. London: Sir Isaac Pitman and Sons, Limited. [Price 6d. net.]

The Induction Motor and other Alternating Current Motors. Their Theory and Principles of Design. By B. A. BEHREND. Second edition, revised and enlarged. New York and London: McGraw-Hill Book Company, Inc. [Price 24s. net.]

The Engineers' Standard Catalogues, 1921–24. Second edition (Home). London: The Standard Catalogue Company, Limited.

The Mechanical Handling of Goods. Modern Methods and Equipment for the Mechanical Handling of Goods in and about Factories, Workshops, Warehouses, Stores, Power Houses, &c. By C. H. WOODFIELD, M.I.Mech.E. London: Sir Isaac Pitman and Sons, Limited. [Price 2s. 6d. net.]

Ministry of Public Works, Egypt. Physical Department Paper No. 4. *Report of Investigations into the Improvement of River Discharge Measurements.* Part I. By E. B. H. WADE, M.A. Cairo: Government Press. [Price P.T. 5.]

The Tools of Man. By JOHN HILL. London: Hodder and Stoughton. [Price 2s. 3d. net.]

Earthwork in Railway Engineering. By JOHN W. F. GARDNER, M.Inst.C.E. London: Constable and Co., Limited. [Price 15s. net.]

The Electric Furnace. Describing the Construction, Working and Applications of all Types of Electric Furnaces. By FRANK J. MOFFETT, B.A., M.I.E.E., M.Cons.E. London: Sir Isaac Pitman and Sons, Limited. [Price 2s. 6d. net.]

TRADE BETWEEN AUSTRALIA AND JAPAN.—The Acting High Commissioner in London for the Commonwealth of Australia reports that the newly-appointed Consul-General for Japan in Australia, on his arrival in Sydney, stated that his mission in Australia was to further commercial relations between Japan and Australia. Japan earnestly desired to improve these commercial relations. He pointed out that last year the Australian exports to Japan in wool, wheat, flour and metals were valued at 8,000,000*l*. Australia's imports from Japan of cottons, silks, enamel ware, fancy goods, &c., on the other hand, were valued at 4,000,000*l*. The trade balance has been in favour of Japan in only two years, viz., 1917–18 and 1918–19.

INDUSTRIAL NOTES.

The Home Secretary has issued three Orders, dated November 8, which he has made in pursuance of the Women and Young Persons (Employment in Lead Processes) Act, 1920. They deal with the meaning of the expression "lead compound" and with the method of ascertaining whether any compound is a "lead compound," they also prescribe the medical examination, and the cloak room, mess room and washing accommodation to be provided.

The accountants to the Board of Conciliation and Arbitration for the manufactured iron and steel trade of the North of England have certified the average net selling price of bars and angles for the two months ending October 31 at 15*l.* 13*s.* 6*d.*, against 16*l.* 13*s.* 4*d.* for the previous two months. On these figures the sliding scale gives a reduction of 10 per cent. on wages. These are now 87½ per cent. above the basis rate.

The ascertainment of selling prices under the Midland Iron and Steel Wages Board shows a fall sufficient to reduce the wages under the sliding scale by 7½ per cent., beginning last Monday. The total drop since the beginning of the year is 155 per cent., but wages are still 110 per cent. above the basis rate of 13*s.* 6*d.* per ton. The puddling rate becomes 28*s.* 4*d.* per ton, compared with the pre-war rate of 9*s.* 6*d.*

Speaking last week at the annual ordinary general meeting of the Cargo Fleet Iron Company, Limited, Middlesbrough, Lord Furness stated that the import of Continental pig-iron into Great Britain for the twelve months ended September 30, 1921, was 517,811 tons, as compared with 193,400 tons for the year ended September 30, 1920. The import of finished steel for the same periods was 627,961 tons and 359,700 tons. In addition, corresponding increases of exports from the Continent to our principal overseas markets simultaneously occurred and perhaps even to a larger extent. Other figures quoted by Lord Furness are the following:—The railway carriage charge on coal and coke, iron ore and limestone, lime, basic bricks, general stores, and for the delivery of 1 ton of finished steel, amounted in July, 1913, to 19*s.* 8·34*d.*, and in October, 1921, to 41*s.* 11·33*d.*, an increase of 113 per cent. On the other hand, the company's price for steel sections in July, 1913, was 7*l.* 10*s.* per ton, as against 10*l.* per ton in October, 1921, an increase of only 33·33 per cent. He viewed the present condition of trade with concern, but believed the country would surmount the present difficulties and re-establish trade on a firm and lasting foundation, provided capital and labour were prepared to work harmoniously together.

The Board of the Bradford Dyers' Association has passed the following resolution, which has been sent to the Railway Managers' Sub-Committee, the Railway Clearing House, and the Coalowners' Association:—"This association, which is a very large user of coal in its 38 works, recognising the need for immediate efforts to promote a revival of the country's trade by a reduction in the cost of production, and realising that cheaper coal is an essential factor in bringing the present stagnation to an end, urges upon the railway companies, in the interests of industry as a whole, the necessity of immediate substantial reductions in railway rates for coal, which, with most other costs, still remain at the highest peak of 1920; and associates itself with the applications of the Mining Association and the industrial consumers generally for such reductions."

It is reported that the South Wales coalowners have agreed to grant a special subsistence allowance to the lower-paid men, in order to raise their minimum wage up to 7*s.* 2*d.* per day. In this connection, Mr. Finlay Gibson, secretary to the South Wales Coalowners' Association, announced that there can be no improvement on this offer, as costs must be kept down. He added that the present cost of production exceeded the price of coal and that in October the loss on working the coal industry was 450,000*l.*, exclusive of capital charges and other items. A special delegate conference of the South Wales Miners' Federation met at Cardiff to consider the question of this 7*s.* 2*d.* minimum, when it was decided to refer the matter to the districts to decide whether the offer should be rejected or submitted to Lord Buxton, the independent chairman, for his ruling.

It is announced that, owing to scarcity of orders, the Hodbarrow iron mines, Millom (Cumberland), closed last Saturday until further notice. They employed about 2,000 men.

The daily press states that meetings of the Labour Party are to take place in London to deal, among other subjects, with the economic clauses of the Treaty of Versailles, when resolutions are to be passed referring to "the destruction of Central European trade and markets," and so forth, matters which, being purely political, are outside our province. The Labour Party would be much better employed in devising means to make good the destruction of British trade and markets. German trade and markets are not in so desperate a condition as is made out.

Sir Frederick Mills states the truth in the first issue of *The Ebbw Vale Works Magazine*—a publication we are glad to welcome—when he gives as a certainty the eternal law that everybody who is capable of working must work. "It may be true," he adds, "that before the war a limited number of persons were enabled to exist, without working, on the surplus created by a long series of years of comparative prosperity; but this is far from being the case to-day, and we must all begin at the beginning again. The determination to work, like the determination to do anything else, is half the battle. If suddenly everybody in the whole world decided to perform his pre-war duties, and ceased to be concerned in his neighbour's politics, I am convinced that in a very short time matters would resume normality, and the exchanges would right themselves."

Mr. Vernon Hartshorn, M.P., has been elected president of the South Wales Miners' Federation, in succession to the late Mr. James Winstone, whilst Mr. Oliver Harris has been elected statistical secretary and treasurer, the latter succeeding the late Mr. Alfred Onions.

The publication of a series of articles dealing with Trade Union Funds, was commenced in *The Morning Post* of last Monday. Striking features of these articles are the increase in the expenses of management of the unions between the years 1918 and 1920, and the fact that in several instances the expenses of management are greatly in excess of the sums paid out to members as benefits. The following are a few examples covering the year 1920:—Workers' Union, expenses of management 195,860*l.*, plus 12,703*l.* for the political fund, the benefits paid out being 168,897*l.*; Sailors and Firemen, management 144,481*l.*, political fund 2,395*l.*, benefits 21,272*l.*; Electrical Trades, management 75,358*l.*, political fund 1,659*l.*, benefits 47,119*l.*; Dock Workers, management 110,472*l.*, no political fund stated, benefits 35,268*l.*; National Union of Railwaymen, management 255,065*l.*, political fund 43,564*l.*, benefits 97,932*l.* Taking 15 unions selected at random and including the above the journal finds that their management expenses amounted to 591,544*l.* in 1918, and to 1,224,144*l.* in 1920, or more than double. From this latter figure it is computed that the management expenses of all the registered trade unions in 1920 totalled about 4,250,000*l.*, apart from political levies.

Taking the National Union of Railwaymen, the total for expenses given above, 255,065*l.*, is made up as follows, leaving out shillings and pence. Salaries and allowances of officers, 80,264*l.*; auditors' fees, 280*l.*; rent, rates and taxes, 7,894*l.*; stationery, printing and postage, 55,504*l.*; expenses of delegates and deputations, 23,947*l.*; travelling expenses, 3,512*l.*; other expenses of management, 83,302*l.* Up to the year 1918, statistics are available showing the totals of revenues, expenditures and funds of trade unions, but no aggregate statistics are available since that year. The following, still quoting from the journal, are figures of expenditure per head of all registered trade unions:—

	On Benefits.	On Direct Politics.	On Management.
	s. d.	*s. d.*	*s. d.*
1911	20 6	nil	6 10
1918	8 10	0 6	8 9

Taking the 1918 totals, the revenue from members of all registered trade unions was 6,231,618*l.*; benefits paid out (including strike pay), 2,225,395; direct payments to politics, 130,460*l.*; management expenses, 2,138,481. As noted above, management expenses have more than doubled between 1918 and 1920.

Flexible Shaft for Light Drives.—We have received from Messrs. Fraser and Glass, of Assembly Works, Middle-lane, Hornsey, London, N. 8, a sample of their new "Uniflex" flexible shaft for driving speedometers, dental engines, horse clippers, portable drills, &c. It consists of a steel chain with alternate pin joints at right angles to each other, enclosed in a flexible metallic tube. The design appears to be mechanically satisfactory and easy to couple up to the work. The method of construction permits of the chain links being very short, thus rendering the drive as flexible as possible, and as the tube is filled with grease all joints are amply lubricated.

THE BRISTOL AERO ENGINE STARTER.

Some particulars of what appears to be a particularly simple and effective means of starting aero engines having six or more cylinders and developing up to 500 h.p., have been issued by the Bristol Aeroplane Company, Limited, Filton, Bristol. The apparatus, which may be installed in any convenient position at any distance from the main engine, comprises a small air-cooled, single-cylinder, two-stroke motor coupled to a pumping cylinder, which draws combustion mixture from a carburettor and delivers it under pressure to the main-engine cylinders. Between the latter and the pumping cylinder is a small disc-valve distributor driven at half speed by the main engine, and this allows the gas to pass into each of the main cylinders on the firing stroke and on a part of the induction stroke; a non-return valve is fitted to each cylinder to isolate the starting apparatus when the main engine is running.

The auxiliary motor is fitted with a two-cylinder magneto, the second lead from which is connected to the central terminal of the distributor on one of the main engine magnetos. When the auxiliary motor is started by means of a hand lever and geared quadrant, the gas supplied to the cylinders of the main engine causes the latter to turn round at from 12 r.p.m. to 15 r.p.m., and as gas is also admitted on the induction stroke, when the inlet valves are open, the gas fills the whole of the main induction system. To avoid loss of pressure through the open inlet valves, the port in the distributor which is in communication with the cylinder at this portion of the cycle is provided with a spring-loaded ball valve arranged to open at about 40 lb. pressure, according to the particular type of engine to be started. The gas is, of course, drawn into the engine cylinders on the induction stroke, and can be fired by operating a switch in the lead connecting the auxiliary engine magneto with that of the main engine, which will then pick up on its own carburettors.

The auxiliary motor will maintain a gas pressure of 140 lb. per square inch, which is sufficient to turn the most troublesome engine, and it should be mentioned that the induction pipe of the auxiliary motor is arranged so that the mixture supplied to the main engine is considerably richer than that supplied to the auxiliary motor, so as to allow for the subsequent dilution in the main-engine cylinders. The weight of the starting apparatus is 40 lb. complete, but it should be noted that the usual hand magneto and dope pump can be dispensed with. After the main engine has been started the auxiliary motor can be run continuously at full throttle for driving auxiliaries, such as the wireless generator, the cooling being assisted by fan blades formed on the flywheel. Both power and pump pistons of the starting motor are of aluminium and are 3 in. in diameter, while the stroke is 2½ in. in both cases. The crankshaft runs in ball bearings, and the "petroil" system of lubrication is employed.

The late Mr. George Fowler.—We regret to have to announce the death, which occurred on Friday last, the 2nd inst., at his residence, Basford Hall, Nottingham, of Mr. George Fowler, a well-known mining engineer. Mr. Fowler was 81 years of age. He was articled to the late Mr. J. T. Woodhouse in 1856, from which time and for a period of over fifty years he was fully engaged in his profession in the colliery fields of the Midlands. In 1869 he was engineer to the Hucknall Collieries, and was appointed a few years later manager of the Babbington Collieries, the two raising at that time 750,000 tons of coal per annum. During his career, Mr. Fowler designed a large amount of hauling, ventilating and winding machinery for the extension of the above-named collieries. He became a member of the Institution of Civil Engineers in the 'seventies. Mr. Fowler was a justice of the peace, and regularly sat on the bench at Nottingham. His only son, Lieutenant-Colonel G. H. Fowler, was killed at Hohenzollern Redoubt whilst in command of the 8th (T.F.) Sherwood Foresters, in October, 1915.

The Second Air Conference.—The first Air Conference organised by the Air Ministry and held in the Guildhall, London, in October, 1920, proved so useful in focussing attention on the many problems of aviation, that it has been decided to hold a second conference in the same place, on February 7 and 8, of 1922. On this occasion the conference will concern itself mainly with the question of the future of aviation, with special reference to its development for commercial transport, and the papers will be divided into two groups dealing with civil aviation in general and with technical problems, respectively. The former will be delivered in the morning of the first day and the latter in the afternoon, while the second day will be devoted to the discussions of these papers. Arrangements are being made to permit members of the conference to visit the Croydon Aerodrome, if they desire to do so, on Monday, February 6, when the operations of the various Continental air transport companies will be shown and explained. As many types of civil aircraft as possible will be concentrated at Croydon at the time of the visit, and demonstrations of amphibian aircraft alighting on the Thames will also be given during the period of the conference.

MAAG GEARING.*

By Engineer-Lieutenant Commander L. J. LE MESURIER, R.N.(Ret.), (Member).

WITH the development of the steam turbine, of high-speed electric motors and other fast-running machinery, gearing has been called upon to work at speeds and loads far beyond the capacity of ordinary straight-tooth spur gearing, which for such purposes has failed to provide either a quiet or a durable drive. This deficiency of the spur gear was mainly due to inaccuracy in the methods of production and also because, in time, the tooth profiles, although possibly accurate at the start, became worn, and lost their correct shape after use. The operation of such gears proving unsatisfactory, the double helical type of gear was introduced, and by providing continuous meshing of a large number of teeth the effect of individual tooth errors was minimised. A vast amount of care and ingenuity has been displayed in various directions in the manufacture of double-helical gearing, and notably successful results have been achieved, particularly in the case of large, single-reduction turbine gears for warships. It cannot be denied, however, that the double helical gear has not maintained in all cases this high reputation.

Double-reduction gearing has proved to be a more difficult problem, and has so far been solved in the case of double-helical gears, mainly by adopting much lower tooth pressures than in the case of single-reduction gears. Attention has also been paid to the important matter of torsional oscillations in the shafting, leading to the development of the "Nodal" drive, in which the natural vibration period of the shafting is suitably altered by dimensioning the shafts and modifying the rotating masses to remove intermittent shocks on the gears due to this cause.

There are admittedly, however, certain features in a double-helical gear open to criticism :—

(1) The gears must necessarily be free to accommodate themselves in an axial direction and the slightest inaccuracies in certain directions in tooth form or pitch cause relative axial displacements of the gears. The rapidity of these movements, taken in conjunction with the masses acted upon, can cause an excessive increase in the loading on the teeth.

(2) The production of double-helical gears is more complicated than straight-tooth gears, and a further possible source of error is introduced in the setting of the helical angle. The means of checking the accuracy of tooth form and pitch is less easily accomplished.

(3) The teeth can only be made of material of such hardness that cutting is rendered possible, either by hobbing or planing.

These considerations prompted an investigation into the best means of developing a satisfactory straight-tooth gear and in the system of gearing and methods of production developed by the Maag Gear Company, of Zurich, means have been found which enable straight-tooth spur gears to be employed successfully under conditions demanding the highest possible peripheral speeds and loads per unit width of tooth. These results have been obtained by certain refinements in the methods of production which ensure the requisite degree of accuracy and at the same time provide a tooth form which is considered to give the most favourable conditions of sliding contact during engagement. In addition, by an entirely novel grinding process it is possible to generate a correct profile on a case-hardened tooth surface by means which are independent of the wear which must take place on the grinding disc.

Accuracy.—The shape of the teeth on any pair of gear wheels should be such that the driving shaft of one wheel when moving with uniform angular velocity, transmits to the driven shaft of the other wheel uniform unaccelerated motion. Thus, the motion must be exactly the same as would be produced by mounting on the shafts friction discs of the required diameter to give the desired angular velocity ratio and imparting the motion from one shaft to the other shaft, either by direct contact as in Fig. 1, or by a crossed band as in Fig. 2. Then if there is no slip or stretching of the band it is obvious that if one shaft moves with uniform velocity so also will the other.

The circles shown in Fig. 1 correspond to the pitch circles of a pair of gear wheels, while in Fig. 2 the circles represent the base circles from which the involutes are generated in ordinary involute-shaped teeth. To obtain correct motion contact between the two surfaces of the opposing teeth must take place along the line A B which crosses the centre line $O_1 O_2$ in the point K. The angular-velocity ratio between the shafts is

$$\frac{O_1A}{O_2B} = \frac{O_1K}{O_2K} = \frac{\text{pitch circle of } O_1}{\text{pitch circle of } O_2}$$

In order to test the accuracy of a pair of gear wheels the Saurer testing machine shown in Fig. 3 has been devised to compare the motion produced by the gears with the correct motion produced by a pair of ground discs of the necessary diameters and connected by a crossed steel band.

Shaft E carries one of the gears A and is also fitted with a ground steel disc at D. The other gear B is mounted on a hollow shaft which is free to move relatively to an inner shaft carrying another ground disc C, which is connected by a crossed steel band with disc D. It will be seen that when motion is imparted by movement of the band the inner shaft carrying the disc C, and the outer shaft carrying the gear wheel B, will both rotate in the same direction, and that relative motion will only occur if the motion imparted by the gears differs from that imparted by the bands and discs.

Fig. 5 shows a diagram obtained from a pair of wheels which were accurately cut and then case-hardened. It will be observed that there are clearly-defined variations arising from each tooth, *a*, *b*, *c*, *d*, &c., as it comes into and leaves engagement.

Fig. 6 is also taken from a case-hardened gear wheel which has not been ground. In this case the wheel had four key ways, and the inaccuracy of the individual teeth and also the distortion due to the key ways is clearly shown.

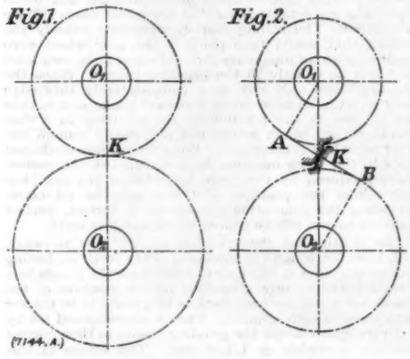
Fig. 7 shows a diagram of a gear wheel the teeth of which were case-hardened and afterwards ground by a method where the tooth surface is not a generated one, the profile inaccuracies being clearly shown. The surfaces of the teeth are smooth and show a great improvement over a case-hardened unground gear, but it is evident the motion transmitted is neither uniform from tooth to tooth nor periodically, the latter being shown by the fact that the general nature of the curve departs in places from an uniform spiral.

Considering the nature of the errors as indicated in the foregoing diagrams, it will be readily appreciated that the tooth-to-tooth errors are far more serious than the periodic errors shown by a gradual divergence of the curve from a true spiral. Each radial displacement of the pencil registers a definite change in angular velocity ratio of the wheels, which occurs while two particular teeth are in contact. In the case of high-speed gearing this represents a very short period of time in which to effect a definite change in angular momentum of the two shafts and their rotating masses, and causes additional loading on the teeth proportional to the rate of change in angular momentum.

The gear-testing machine described is applicable only to small gears for motor cars, machine tools, &c., but the nature of the diagrams serves to show what has to be accomplished in developing a satisfactory spur-tooth gear applicable to the high speeds and loads common in turbine and in electric-traction practice. It is at least essential that the tooth profiles and pitching of the teeth should have the highest possible degree of accuracy so that true kinematical motion is transmitted, and the normal loading on the teeth is not unduly increased, by having in addition to deal with rapid changes in the angular momentum of the rotating masses. Methods for testing the accuracy of larger gears are described later.

Durability.—Due to the loading on the teeth and the partial sliding and partial rolling action which must always occur when a pair of gear wheels are in operation, wear is bound to take place, and in order to preserve the initial accuracy it is naturally of the greatest importance that wear should be reduced to a minimum. The principal factors governing the amount of wear which will take place are the loading per unit width of the gear teeth, the material of the engaging surfaces of the teeth, the conditions under which engagement takes place, and the lubrication of the tooth surfaces.

Wear can generally be reduced in any type of gear by increasing the width of teeth, provided the ratio of width to diameter in the pinion does not become so great that, due to torsional effects, the tooth surfaces do not bear across the whole width of the tooth. It is, of course, desirable that the overall dimensions of any gears should be the minimum possible consistent with obtaining satisfactory results in practice. It is not possible to give a definite figure as to the maximum load per unit width that a particular type of gear can carry, as this depends upon the conditions of service and also very largely upon the material of the tooth surfaces and the radius of curvature of the tooth profiles. In examples given later the load per unit length and also the empirical



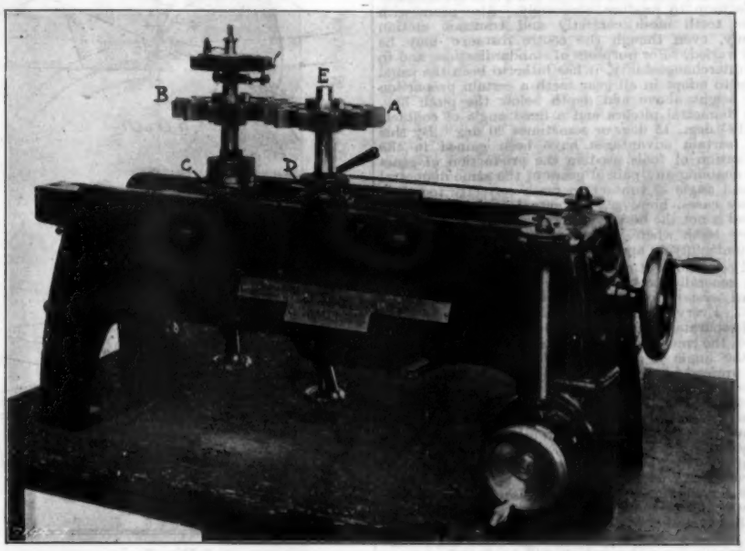
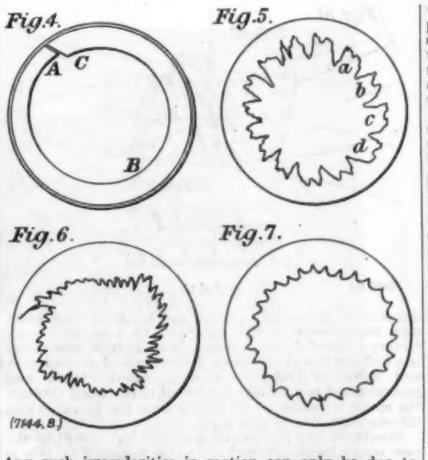


FIG. 3. THE SAURER GEAR TESTING MACHINE.



Any such irregularities in motion can only be due to inaccuracies in the gears, and by a suitable multiplying mechanism a record is made on a diagram by a pencil which registers any relative movements between the inner and outer shafts.

Fig. 4 shows a diagram from a pair of accurately-ground wheels. The curve A B C is an uniform spiral and shows that the pencil has, during the complete rotation of the card, moved uniformly in a radial direction a total distance A C, which is a measure of the relative motion of the inner and outer shafts carrying the disc and wheel respectively. In this particular card the ratio of disc diameters was purposely made to differ slightly from the ratio of the pitch circle diameters of the wheels, thus accounting for the relative angular displacement of the shafts.

* Abstract of a paper read at the meeting of the North-East Coast Institution of Engineers and Shipbuilders, on November 22, 1921.

rule adopted by Messrs. Parsons giving P/D and P/$\sqrt{D}$, are quoted for various types of Maag gears.

The means provided in Maag gears for securing that the highest possible load is carried, are dependent mainly on providing a case-hardened and ground surface on the teeth, which is the best possible surface to resist wear, and also on designing the teeth to give the most favourable conditions of action during engagement whereby the relative movement between the opposing teeth partakes more of a rolling than a sliding action.

In small, high-speed, heavily-loaded gears both wheel and pinion are case-hardened and ground, but in large gears, where grinding becomes impracticable, the tooth load is reduced and the wheel teeth are simply planed. The combination of a case-hardened and ground pinion and a wheel having relatively soft teeth is found to give very good results as the smooth, accurate surface of the hard pinion teeth produces a burnishing effect on the wheel teeth which greatly prolongs their life. This effect has been clearly demonstrated in Maag electric-traction gears adopting this arrangement.

Shape of Teeth.—It is well-known that the involute shape of tooth possesses certain attributes which render it particularly suitable, both from a manufacturing point of view and also for meeting the conditions arising in practice. This involute-shaped tooth can be generated from a straight-sided rack cutter, which is of the simplest possible form to produce accurately. Also gears with involute teeth mesh correctly and transmit motion uniformly, even though the centre distance may be slightly varied. For purposes of standardisation, and to secure interchangeability, it has hitherto been the usual practice to adopt in all gear teeth a certain proportion in the height above and depth below the pitch line, certain diametral pitches and a fixed angle of contact, either 14½ deg., 15 deg. or sometimes 20 deg. By this means, certain advantages have been gained in the simplification of tools used in the production of gears and in enabling any pair of gears of the same diametral pitch and angle of contact to mesh correctly together. In many cases, however, the actual form of tooth so produced is not the best, particularly in the case of gears with few teeth where, unless certain modifications are made, undercutting and weakening of the tooth results.

Ideal conditions of relative motion between the teeth cannot generally be obtained by the adoption of any standard system of tooth proportions or angles of contact. Every particular pair of gears requires to be studied separately and the best shape of tooth designed to give the most satisfactory results. In all Maag gears the angle of contact and dimensions of teeth are determined in the first place by consideration of the ideal conditions of engagement and are practically unaffected by the question of how such teeth are to be produced. The most favourable conditions for every case have been determined by careful calculations based on a systematic comparison of a very large number of gear ratios, and from these a range of tools has been prepared which enables all gears to be cut by these tools without any reference to standardisation of pitches, pressure angles or tooth proportions.

In all cases the tools used are straight-sided rack cutters with a standard pressure angle of 15 deg., while in the grinding machine, which will be described later, the angle of the grinding planes is also 15 deg. From these standard tools the required variation in pressure angles to obtain ideal conditions of engagement is obtained on the well-known principle of generating the gears at a certain pitch circle, but running them at another pitch circle. While this principle is not new it has been exploited to the fullest extent in the Maag system, the whole series of tools having been designed expressly for this purpose.

The following examples serve to show the nature of the alterations in tooth form adopted in the Maag system.

Figs. 9 and 10 show the difference between the tooth forms of a pair of 21-teeth wheels with ordinary standard form of tooth with a 15-deg. pressure angle, and a similar pair of gears with the Maag form of tooth. By suitably dividing the tooth profiles of one tooth and marking on the opposing tooth the points where these divisions meet during engagement, the nature of the relative motion between the teeth can be readily seen. Thus, the point A1 on wheel A eventually meets point B1 on wheel B, point 2 on A meets 2 on B, &c. Owing to the difference in the lengths A1—2 and B1—2 the action which occurs while these parts of the tooth profile are in contact, consists of a motion which is partly rolling and partly sliding. It can only be pure rolling if the lengths are exactly the same, and it is evident that it is not pure sliding since part of the relative movement is accomplished by rolling. The degree of sliding can be best represented by assuming that the two portions of the teeth in question roll together over a distance equal to the length of the shorter piece and slide the remainder of the distance. Proceeding for each divided portion in this manner and plotting out the results to a larger scale, the effect of the relative amount of sliding and rolling action is shown in the scales below each diagram.

It will be seen that in the Maag gear the degree of sliding is very much less, while the degree of rolling is substantially increased; also, the tooth form is much stronger, owing to a wider section at the base, and the length of the active tooth profile is substantially increased.

Fig. 8 shows a 5/50 gear ratio in which a pinion is provided with only 5 teeth, and which produces a gearing kinematically correct, and of ample strength and good wearing properties. There is no claim in the Maag system of gearing to any new principle. By the application of well-known principles, however, means have been devised for covering the whole range of gearing for ordinary requirements in such a manner that the best shape of profile is obtained in all cases. The resulting reduction in the degree of sliding action, combined with the fact that the tooth is strongly proportioned with a wide section at the root, and a long active profile, has been found to contribute in no small measure to the reduction of friction and, therefore, to increase the durability and efficiency of the gears.

Lubrication.—In all cases oil is the most satisfactory lubricant for high-class gearing. Grease is not to be recommended, as in the course of time grit and other foreign matter collect and convert the grease into a grinding paste which is injurious to the surface of the teeth. Maag electric traction gears for locomotives and tram cars are, whenever possible, provided with oil-drip lubrication. In the case of hardened and ground gears for turbine reduction sets, it is of interest to note that the usual practice adopted with double-helical gears of

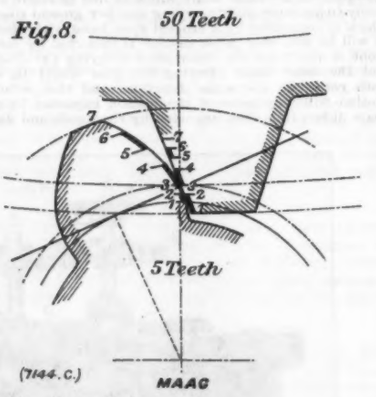


Fig. 8.

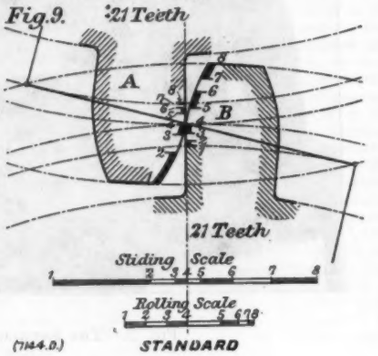


Fig. 9.

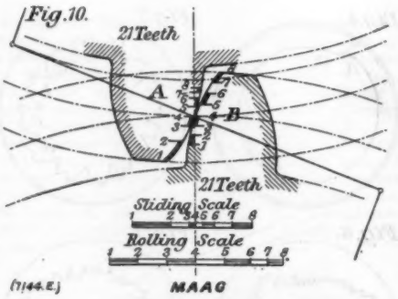


Fig. 10.

directing a jet of oil between the teeth as they enter into engagement is not found to be the most satisfactory. Careful observations have proved that there is a definite loss of efficiency if this method is employed, and sufficient lubrication with case-hardened and ground gears is provided by the oil mist caused through the spray diffusion of oil issuing from the bearings and thrown outwards by the gears.

Should cooling have to be provided for, as will be the case where large powers have to be transmitted, this is best arranged by directing the oil jet on the teeth as they leave engagement. In an actual case, with a reduction set of 250 b.h.p. running at 6,000 r.p.m., it was found that the efficiency when spraying the oil jet between the teeth was 96 per cent., but while using spray diffusion it was as much as 98·5 per cent. In the former method there were thus the equivalent of 6·25 h.p. to be absorbed by the oil in the form of heat, thereby necessitating the provision of much larger oil coolers.

Production.—Fig. 11 shows a standard type of Maag gear-cutting machine. It will be observed that the tool consists of a straight-sided rack-cutter supported by a tough steel backing plate so that the tool can be used even when thin after repeated grinding. The tool holder is pivoted horizontally on the ram, the tool being depressed positively at the bottom of each downward cutting stroke so as to give positive clearance on the return upward stroke. The blank remains stationary during the cutting stroke, and the rolling or generating feed motion takes place during the upward stroke. The ram is driven by a slotted link giving a quick return motion, and the stroke can be adjusted by a hand-wheel from the rear.

The generating movement is given to the blank by a dividing worm for the rotational component and the table-fed screw for the transitional movement, the combined movement representing exactly the motion that would be produced if the gear-blank were to mesh correctly with an imaginary rack represented by the cutter. The blank is set at the correct distance horizontally from the cutter to the full depth of the tooth. The generating movement takes place either from the left or right, and on completion the table is returned quickly to its initial position, the wheel blank during this reversal being brought in the correct position for the next tooth. One, two or three pitches can be cut at each motion.

The accuracy of the gears produced is naturally dependent upon the accuracy of the machine itself in reproducing correctly the generating movement, and in dividing or rotating the blank the correct amount at the commencement of each generating movement.

Grinding Machine.—After gears have been cut and then case-hardened, distortion inevitably occurs, and however accurate the cutting process may have been the condition of the teeth after hardening would be such that it would be quite impossible to use them in any high-speed gearing. The Maag grinding machine provides a means of developing by a generating process, which is independent of the wear of the grinding disc, an accurate surface on the tooth profile.

The principle of the machine is illustrated in Fig. 12, and the machine itself in Fig. 13. Generation is effected by giving the gear C, which is being ground, a rolling motion to and fro across the planes formed by the projected edges of the hollow shaped grinding discs B, which are driven by two small motors M. At the same time a slow feeding motion takes places forward and backwards along the table L, so that the whole tooth surface is covered. The rolling motion represents exactly the motion that would take place if the gear wheel were meshing with an imaginary straight-sided rack, two sides of which lie exactly in the grinding planes. Since the grinding discs only cut on a comparatively thin edge the projection is necessarily a perfect plane and is thus not subject to the possible errors occurring in a flat-grinding disc, which would not necessarily remain flat after wear had taken place. Wear on the saucer-shaped discs in the Maag machine does not disturb the perfect plane produced by the projected edge of the disc, but only alters the position of the plane. In all cases, providing the generating movement is correct, perfect involute curves will be generated on the gear teeth.

The shifting of the grinding planes, due to wear, will, however, affect the thickness of the teeth as, having ground the sides of one pair of teeth with the planes in a certain position, any alteration in the position of the planes will cause the next teeth to be ground to be thicker than those already ground. This is compensated for by a device which keeps the grinding planes in their correct position to within ± 1/1,00 mm. The action of this compensating device is as follows:—Every six seconds or so a pivoted arm A, Fig. 12, carrying a flat diamond at its extremity, is allowed to advance until the diamond touches the edge of the grinding disc. If the disc is in its correct position, *i.e.*, if no wear has taken place, the lever is held up at this point by the edge of the disc and no compensating action is needed. Assuming, however, that the disc has become worn during the six seconds interval, the diamond proceeds beyond the correct position of the plane, and in doing so it makes an electric contact which completes the circuit of a solenoid. The effect of this is to set in action a mechanism which, by means of a differential screw, brings back the grinding disc a total distance of 1/1,000 mm. In this way compensation proceeds intermittently according to the amount of wear taking place, and the planes are kept in their correct position to within ±1/1,000 mm, its action being sufficiently reliable to enable soft or hard grinding wheels to be used indiscriminately. For good production soft rather than hard-grinding wheels are preferably employed.

The wheel C to be ground is mounted on a mandril carried by the dividing head D and spindle at one end, and supported in a fixed centre at the other end. The dividing head and fixed centre are themselves fitted to a carriage E, which is given a reciprocating motion transversely to the grinding planes, thus providing one component of the rolling or generating movement. The other component, *i.e.*, the rotary motion, is obtained by means of a pitch block F having a cylindrical surface, around which are wrapped four steel ribbons, two of which pass to one side of the ribbon stay carriage G at H, and two to the other side at K.

Assuming that the ribbon stay carriage G is fixed, it will be seen that as the carriage E is reciprocated transversely, the pitch block and gear C will also receive a rotary motion exactly as if the pitch block F were rolling along the line HK. If the ribbon line HK represents the pitch line of an imaginary rack cutter and the pitch block, the pitch circle of the gear C being ground, the pitch block and, therefore, the gear C to which it is connected, will describe a pure rolling motion to and fro along the line HK.

To obviate having to provide a separate pitch block for each pitch circle diameter of various sizes of wheel to be ground the points HK are attached to the ribbon stay carriage G, which can be given a reciprocating movement that exactly compensates for any difference in diameter between the pitch block and pitch circle diameter. This movement is transmitted by the slotted

MAAG GEAR-CUTTING AND GRINDING MACHINES.

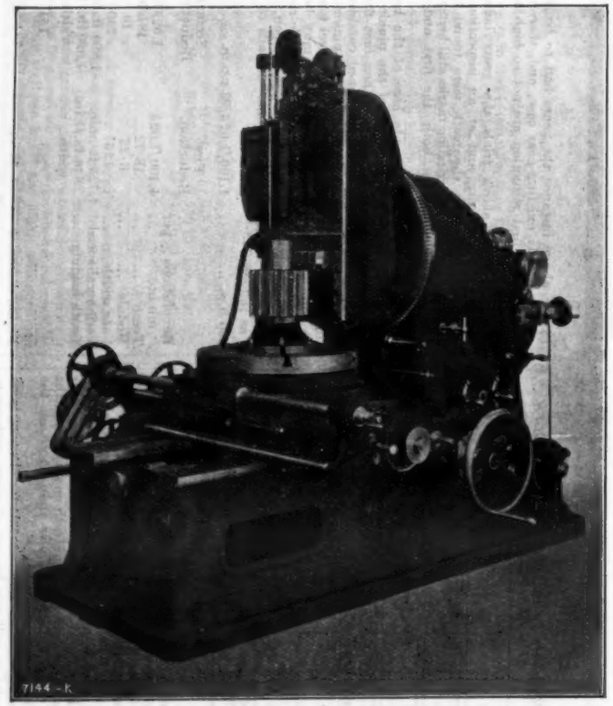


FIG. 11. GEAR-CUTTER.

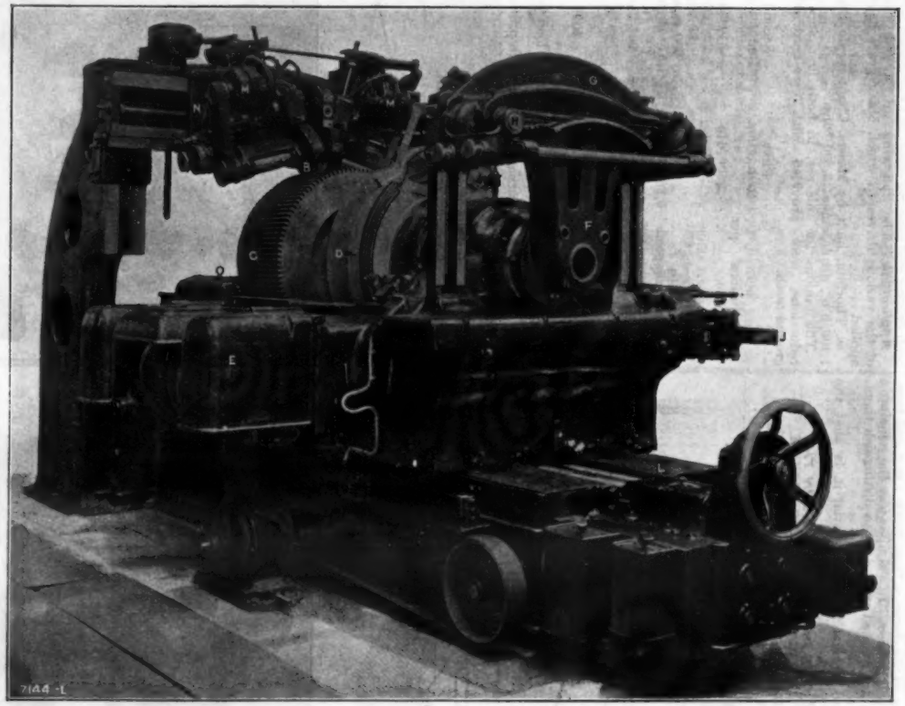


FIG. 13. GRINDING MACHINE.

bar J which rocks on a vertical axis that can be altered to vary the ratio of the two arms of the rocking-bar. It is thus only necessary to provide nine different pitch blocks to cover all sizes of wheels up to the maximum diameter of 32 in. with which this particular machine can deal.

In addition to the generating movement, the work carriage receives a slow feeding motion forwards and backwards along the table L, and the stroke can be varied according to the width of the wheel being ground. After grinding a pair of profiles during one such passage the work is automatically rotated or divided by means of the dividing head D, at the end of the stroke so that on the next passage another pair of profiles are ground.

The cross slide N carrying the grinding equipment is adjustable vertically in order to accommodate work of different diameters.

In order to test the accuracy of the generating movement an instrument has been devised which records the errors on an indicated drum.

Dividing.—The accuracy of dividing or spacing of the teeth in any form of gearing demands the closest attention. In the Maag gear-cutting machines, dividing is obtained by a worm and wormwheel, and in the grinding machines by a dividing plate with radial slots cut in the periphery. The positioning of the shaft in the grinding machine is obtained by a cylindrical bolt which enters and beds itself on the two slightly inclined ground surfaces of the radial slots.

The manufacture of the dividing worm-wheels and dividing plates is dependent on a machine of high accuracy which has been developed by the Maag Gear Co.

Tests for Accuracy.—While the improved methods of production were being evolved the problem of accurately measuring the teeth of gears was also occupying attention, and the following are some of the methods which were adopted.

The tooth vernier, which was probably one of the first instruments designed to determine the accuracy of gearing, was at one time almost universally used, and is still used by many firms. By means of this instrument it became possible to determine the chordal tooth thickness at a certain depth from the outside diameter, and, further, to compare the thickness of all the teeth at the same depth. The error which may easily arise from this method is clearly shown in Fig. 14 and 15, where, although the teeth are of equal thickness the tooth spaces are unequal. Further, as the teeth are measured from the outside diameter and the gearing itself is afterwards positioned from the bore for running purposes, it is apparent that any eccentricity of the outside diameter with relation to the bore will give false Vernier readings, and this method is consequently insufficient to ensure good running.

It was then decided to provide a means of measuring independent of the outside diameter. A ground cylindrical mandril was positioned in a tooth space, and then the gear rotated with the mandril so that the mandril passed beneath a dial indicator. The movement of the pointer was noted and the process repeated for the remainder of the teeth. This method had an advantage over the tooth vernier method through being quite independent of the outside diameter, but the readings, although more accurate, were incomplete as no indication of the accuracy of the pitch was given.

Both of the foregoing methods being incomplete, further measurements are necessary to include both tooth and space, *i.e.*, pitch. The apparatus adopted consisted of two ground mandrils located in adjacent tooth spaces. On one was clamped an arm carrying a dial indicator, and this arm, together with the indicator, was swung past the second mandril, the maximum reading being noted. The values obtained enabled a comparison to be made of the distance between the centres of any two adjacent tooth spaces.

This apparatus gives improved results, but although capable of measuring to 1/100 mm., this was found to be insufficient, and, moreover, for small pitches the instrument was inconvenient to handle. A further instrument was, therefore, constructed to meet these requirements. The two mandrils were replaced by two ball arms, one being fixed and the other pivoted, and acting through a series of levers on to the plunger of the dial indicator. By these means readings could be taken to 1/1,000 mm., and comparisons made of the distance between the central lines of the tooth spaces anywhere along the gear face. A further comparative set of readings could be taken by fitting ball arms of various sizes and measuring the distance at different tooth heights.

The results achieved were extremely accurate for dividing plates and work of a similar nature, but the readings obtained did not give a true indication of how the gears would run in service as, although the distance from the centre of any tooth space to the centre of its adjacent tooth space may be in every case equal, the important measurement is from one profile to the adjacent profile, and this may quite possibly be unequal.

From this stage the next step was to measure from one flank to the next successive flank as shown in Fig. 16, as when gears are in engagement it is only the driving profiles which are in contact. In order to utilise the instrument already constructed it became necessary to position from the outside diameter of the gear. In doing so, however, the errors in measuring the pitch relativity to the actual pitch circle, which is concentric with the axis but not necessarily with the outside diameter, were considerably smaller than the errors which were present with the tooth vernier method. In Fig. 17 a comparison of these errors is shown.

Assume that the gear is correct in all respects except that the outside diameter has an eccentricity = *h*. This will have no effect whatsoever on the actual running of the gears, the pitch and other vital measurements being assumed to be absolutely correct.

Measurements taken by the tooth vernier method,

however, will show an apparent error = 2 × tan 15° × h, while the error according to the method described in Fig. 16 = $\left(\frac{CP \times (R + h)}{R}\right)$ − CP, where CP = circular pitch and R = radius at which measurement is taken.

Taking a concrete example :—

Number of teeth = 60, module = 7, h = 0·1 mm.

Error according to tooth vernier method

= 2 × 0·2679 × 0·1 = 0·053 mm.

Error according to method Fig. 16—

$= \left(\frac{22 \times (420 + 0 \cdot 1)}{420}\right) - 22 = 0 \cdot 004$ mm.

A gear which is in reality absolutely true as regards pitch may thus show incorrectly a much greater error if measured by the tooth vernier method, than according to the method shown in Fig. 16.

In order, however, to be quite independent of the outside diameter this instrument was next affixed to a swinging arm. The arm was made to swing about its lower centre, and fitted with joint and locking nut for adjustment purposes. The instrument was then quite independent of the outside diameter, and it became possible to take readings from any two adjacent profiles at different heights and directions, thus checking one series of values with the others. The values obtained gave to a great extent an indication of how the gears would actually behave in service, and proved that the methods were proceeding along proper lines.

One very important feature of the instrument was that the distance could be measured between two adjacent profiles as they would actually make contact when

Fig. 14.

coming into engagement, *i.e.*, along the common normal to the two profiles. By adjusting the swinging arm it is possible to bring the two ball arms along this common normal, the measurements obtained giving a still clearer indication of how the gears would actually behave. The apparatus became so sensitive when measuring in this way that the slightest unevenness of the tooth profile was registered, and to obtain a more average reading small swivelling-shoes were fitted to the ball arms.

As all Maag gears are ground from their actual shaft bearings the teeth are absolutely correct with the relation to the bore, and consequently by modifying the measuring instrument as shown in Fig. 18 it could be made in a more convenient form and, also, used to measure gears after their removal from the machine.

Seeing that the tooth profiles are parallel when measured along their common normals and, further, that this is always the shortest distance between the two profiles, the instrument may, by substituting a planed surface for the fixed ball arm, be used to determine the comparative distances between any two adjacent profiles of a gear (Fig. 18). These measurements, being made exactly where the teeth profiles would come into contact with the engaging gear teeth, give a very sure indication as to how the gearing will eventually run, providing the profiles are correct.

In order to secure satisfactory running for high-speed gearing it is essential that these tooth-to-tooth errors do not exceed a certain figure, which may to some extent, be fixed for various peripheral speeds and conditions. For speeds above 10,000 ft./min. these errors should not exceed 0·005 mm., and it will be realised that only the highest class of machinery can be utilised for the production of such gearing. Even then it is found advisable to discontinue automatic grinding when the accuracy is within about 0·01 mm., and to make necessary corrections afterwards to the individual teeth.

A diagram of a gear after automatic grinding and correction is shown in Fig. 19, where it will be seen the final maximum tooth-to-tooth error is 0·005 mm. and the maximum periodic error 0·1 mm. It will be observed that the system adopted for plotting out the tooth-to-tooth differences enables these corrections to be made easily. For instance : from tooth 1 to 2 there is a value of + 0·005, and from 2 to 3 a value of — 0·005. Therefore, if from the profile 2 an amount of 0·005 is ground, the difference in the distance from tooth 1 to 2 and from tooth 2 to 3 will be zero. In a similar way the remaining teeth, which are marked with dots to distinguish them, may also be corrected.

In order to emphasise how essential it is that the

Fig. 12. THE PRINCIPLE USED IN THE MAAG GEAR GRINDING MACHINE.

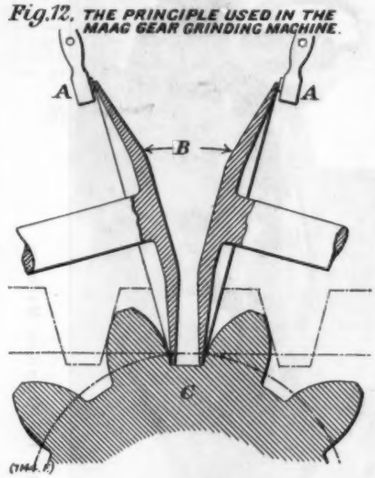


Fig. 17.

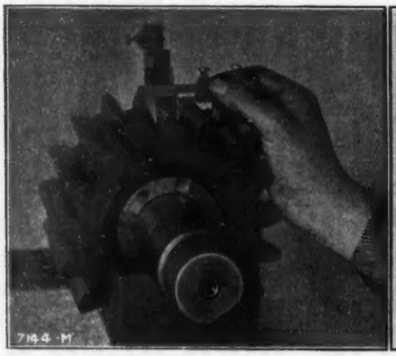


FIG. 15.

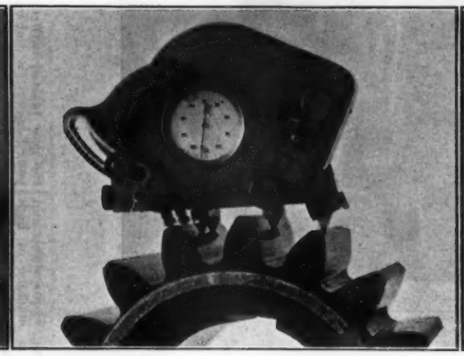


FIG. 16.

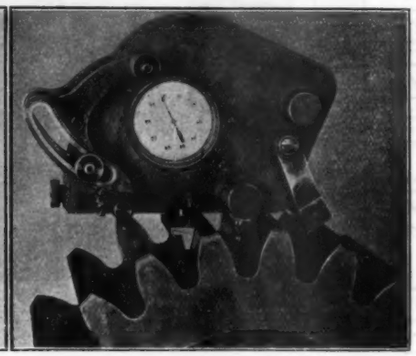
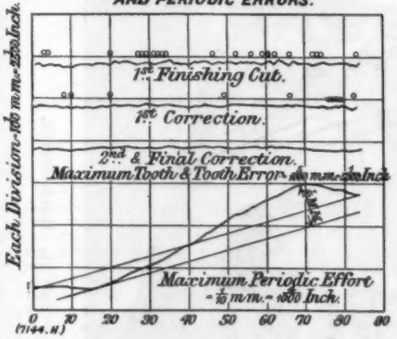


FIG. 18.

Fig. 19. DIAGRAM OF PLOTTED TOOTH TO TOOTH AND PERIODIC ERRORS.



tooth-to-tooth measurements should be made by proper methods the case of a corrected gear may be taken where, during correction of the individual profiles, the measured periodic errors for the driving profiles and for the coasting profiles may both occur on one side of the gear. In service this gear would give absolute satisfaction, but if measured by any tooth vernier method the gear would appear to be useless as the teeth on one side of the gear would admittedly be thinner than those on the opposite side.

While dealing with the requirements for ensuring good running results it will not be out of place perhaps to mention one point which is sometimes credited with affecting the running, *i.e.*, "back-lash," or play between the teeth profiles. Providing the gearing is suitably designed and has correct profiles and pitch, the running of the gear will not be affected in the slightest by the gear having either 0·4 mm. or 0·8 mm. play. With the natural tendency of the gears to become heated and to expand before the casing, it is obviously far safer to have too much play rather than too little, as in the latter case there is the possibility of the gears bearing on both driving and coasting sides, and eventually jamming.

Applications.—The following are a few examples of the various drives to which Maag gears have been applied :—

ss. Thorium, built by Messrs. Chantiers de Bretagne, 1,100 h.p., displacement 3,800 tons.

The pinions for this set, in both first and second reductions, were provided with case-hardened and ground teeth.

	First Reduction.	Second Reduction.
Revolutions per minute ...	3,500/610	610/70
Teeth	29/166	22/192
Module	5·99	11·2
Face width ...	200 mm.	300 mm.
Peripheral speed	6,300 ft./min.	1,570 ft./min.
Tooth loading per 1 in. width ...	365 lb.	965 lb.
$\frac{P}{d}$	53·8	99·5
$\frac{P}{\sqrt{d}}$	—	309

$\frac{P}{d}$ being to some degree the relation of the load per 1 in. width of tooth to the curvature of the tooth profile.

In the above instance the gears had to be designed to fit an already existing gear case, and, therefore, the figures for the first reduction are not so high as could have been taken.

Throughout the ship's trials the gears behaved in every way satisfactorily, and at an inspection of the gears made afterwards the teeth were found to be in excellent condition, the grinding marks still being plainly visible on the pinions of both the first and second reductions.

Mention might also be made here of the beneficial effect of the hard, smooth teeth of the pinion on the unhardened teeth of the wheel. When first fitted the wheel teeth were in an ordinary planed condition, but due to the burnishing effect of the hard pinion profiles a polished surface was produced on the wheel teeth.

As another example, the s.s. *Niobe* may be cited. This ship was fitted with Maag double-reduction gearing by The Atlas Company, of Copenhagen, and has now been in service for some time. Details of the set are as follows :—

600 h.p. ... ... 4,100/1,025/92 r.p.m.

	First Reduction.	Second Reduction.
Revolutions per minute ...	4,100/1,025	1,025/92
Teeth	18/72	18/200
Module	6·22	10
Face width ...	125	240
Peripheral speed	4,725 ft./min.	1,890 ft./min.
Tooth loading ...	840 lb./1 in. width.	1,090 lb./1 in. width.
$\frac{P}{d}$	190	154
Pinion diameter	4·42 in.	7·1 in.

In the above the $\frac{P}{d}$ is much higher than would be advisable with unhardened pinion teeth.

Turbo-Generating Gearing.—Maag case-hardened and

ground gears have been successfully applied in a large number of turbo-generator plants, particularly in cases where high peripheral speeds are called for.

The following details are of a turbo-generator reduction set recently erected and tested at Messrs. Fontaine l'Eveque, the results being entirely satisfactory :—

Horse-power	1,800
Revolutions per minute ...	7,500/1,500
Centre distance	450 mm.
Number of teeth	21/105
Module	7·15
Width of face	200 mm.
Peripheral speed	11,600 ft./min.
Tooth loading	640 lb./1 in. width.
Pinion diameter	5·91 in.
$\frac{P}{d}$	108

A further example is of a turbo-reduction gear at Messrs. Trefileries du Havre :—

Horse-power	2,250
Revolutions per minute ...	6,000/2,100
Centre distance	325 mm.
Number of teeth	23/66
Module	7·3
Width of face	280 mm.
Peripheral speed	10,400 ft./min.
Tooth loading	640 lb./ 1 in. width.
Pinion diameter	6·62 in.
$\frac{P}{d}$ ... ... approx.	97

Electric Traction Gears.—In electric locomotive drives, where much has to be brought within the gauge of the

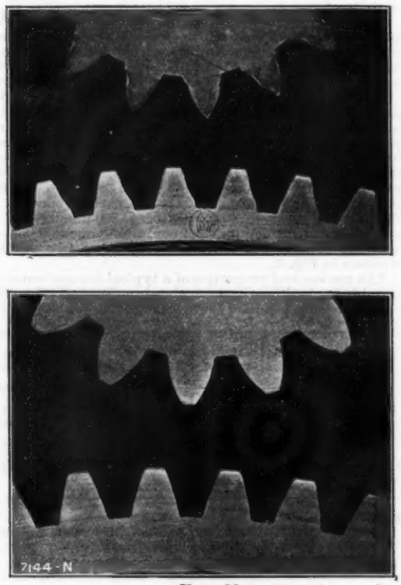


FIG. 20.

railway track and consequently space is limited, the conditions to be fulfilled by the gear-maker are often severe and perhaps, therefore, the following application of Maag gears in this connection may be of interest.

The Swiss Federal Railway required a number of gear drives for their locomotives for the St. Gotthard section, and, for the purpose of making a comparison, it was decided to fit a certain number of these with double-helical gears and an equal number with Maag straight-line toothed gears with hardened and ground pinions. Both types of these gears were made at the Maag Gear Company works, the same care being taken in each case to make them as accurate as possible. As, however, it was impossible to grind the double-helical pinions these were planed in a very hard forged steel and left unhardened.

Particulars of Maag Spur Gears.

Number of teeth	44/125
Module	11
Width	150 mm.
Centre distance	930 mm.
Maximum peripheral speed...	4,530 ft./min.
Normal peripheral speed ...	2,800 ft./min.
Maximum tooth pressure ...	1,680 lb./1 in. width
Normal tooth pressure ...	820 lb./1 in. width
Pinion diameter	19·2 in.
Normal $\frac{P}{\sqrt{d}}$	187

After running in service for nearly twelve months an inspection of the gears was made ; while not the slightest wear was noticeable in the case of the spur gears with case-hardened and ground pinions, a considerable amount of wear was to be observed in the double-helical gearing, and as a result of these trials the Maag straight-lined toothing was finally adopted for all future sets. Fig. 20 shows two sets of tram gearing run under exactly similar conditions, one set having unhardened pinion and the other set having a Maag hardened and ground pinion.

CHROMIUM STEELS AND IRON.*

By LESLIE AITCHISON, D.Met., B.Sc., A.I.C.

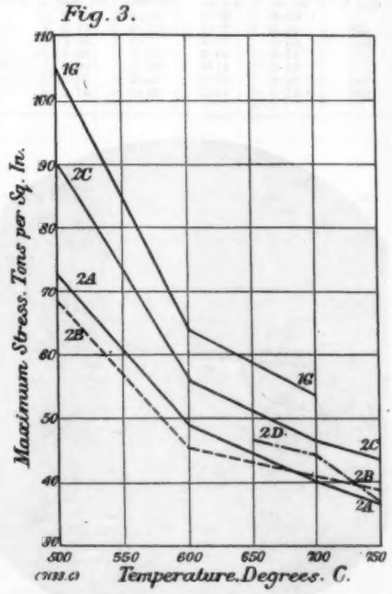
(*Concluded from page* 772.)

IN considering the mechanical properties of the chromium steels, it will be advantageous to study first of all a series of steels of which each member contains approximately the same proportion of carbon but a different proportion of chromium. This can be done by taking the steels of which the compositions are given in Table I.

TABLE I.—*Chemical Composition of First Series of Chromium Steels.*

Mark.	Carbon.	Silicon.	Manganese.	Chromium.	Nickel.
	per cent.	per cent.	per cent.	per cent.	per cent.
1B	0·45	0·12	0·72	1·28	—
1C	0·37	0·11	0·48	2·8	—
1D	0·34	—	0·43	5·09	—
1E	0·44	0·19	0·33	6·0	—
1F	0·44	0·24	—	9·6	—
1G	0·37	0·19	0·15	12·0	0·55
1H	0·47	0·24	0·64	16·07	—

Fig. 3.



To demonstrate the effect of the varying proportions of chromium upon the mechanical properties of the steel, tests can be quoted that have been obtained from samples of each steel which have been heat-treated similarly, *i.e.*, which have been quenched from an appropriate temperature and then have been tempered at similar temperatures. The first series of test results have been obtained upon specimens all of which have been quenched in oil and then tempered at fairly high temperatures, *i.e.*, at such temperatures as would be employed to produce in the steels those mechanical properties that are usually desired by the engineer. The results are quoted in Table II.

The test results given in Table II show at once that the mechanical properties of the different steels containing chromium, after suitable heat-treatment, are of a high order. Even the steel containing only 1 per cent. of that element has very good properties. The tests also indicate that the effect of varying the production of chromium is not very great, and that if only mechanical properties are in request, then the desired results can be obtained by the addition of a comparatively small proportion of the alloying element. The steel having about 3 per cent. of chromium is to be recommended definitely. Its advantage over the 1 per cent. steel is not so obvious from the test figures quoted as it really is in practice, because all the test values that are quoted have been obtained from specimens that have been heat-treated in a fairly small size, *i.e.*, 1½ in. diameter. If the size of the specimen is increased so that there is an opportunity for mass effect to play a part, and to affect the mechanical properties, the 3 per cent. chromium steel gives distinctly better results than those provided by the 1 per cent. steel. This can easily be appreciated by comparing the values of the tensile strength possessed by these two steels (1B and 1C) when cooled normally in the air :—

Steel B cooled in the air (860 deg. C.), 53 tons per square inch.
Steel C cooled in the air (830 deg. C.), 80 tons per square inch.

Evidently the 3 per cent. steel has some air hardening

* Paper read before the Institution of Automobile Engineers, on Wednesday, November 9.

properties which render it able to resist in a great degree the effects of mass during quenching.

The property of hardening in the air becomes very much more pronounced when the proportion of chromium in the steel is raised considerably, *i.e.*, when it approaches the proportion found in stainless steel. Steels with about 12 per cent. of chromium will harden quite regularly to a maximum stress value of round about 100 tons per square inch when they are cooled in the air from a temperature of over 900 deg. C.

Having shown that the chromium steels do possess, when heat-treated in a perfectly simple manner, mechanical properties of a distinctly high order, and that they possess the requisite properties to endear them to the automobile engineer, it may be desirable to pass on to consider the chromium steels which have uses other than for structural details. (Fuller information regarding the mechanical properties of some of the groups of steels that have been discussed above is provided in Appendix A.)

The most obviously interesting group of the special chromium steels and irons is that of the "stainless" materials. It is fairly generally known that these metals contain round about 12 per cent. of chromium, and it is known that they do not corrode or rust when immersed in vinegar or the like. The mechanical properties of these materials are not so widely appreciated. It is also not

Fig. 4.

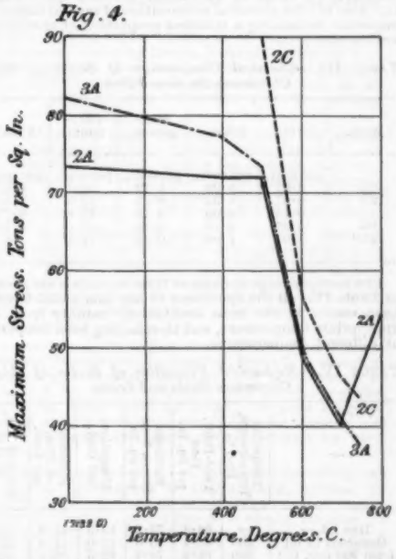


TABLE II.—*Mechanical Properties of First Series of Chromium Steels.*

—	Tempering Temperature, Deg. C.	Yield-Point, Tons per Sq. In.	Maximum Stress, Tons per Sq. In.	Elongation, per Cent.	Reduction of Area, per Cent.	Notched Bar, Ft.-Lb.
Steel 1B.—	600	58·5	64·6	20·0	54·1	21
Quenched in oil	650	49·8	58·1	23·0	60·8	42
from 860 deg. C.;	700	43·2	52·0	26·0	63·7	88
Chromium, 1·28 per cent.	750	32·3	47·1	30·5	69·8	96
Steel 1C.—	600	56·0	61·6	20·0	60·4	28
Quenched in oil	650	47·2	54·4	24·0	62·6	92
from 830 deg. C.;	700	41·2	49·4	25·0	67·8	98
Chromium, 2·8 per cent.	750	37·4	44·0	29·0	70·8	111
Steel 1D.—						
Quenched in oil						
from 850 deg. C.;	700	32·4	44·5	14·7	57·3	67
Chromium, 5·09 per cent.						
Steel 1E.—	500	82·7	91·9	10·0	30·5	—
Quenched in oil	600	49·2	58·7	18·2	49·7	15
from 850 deg. C.;	700	35·4	48·7	23·0	60·4	75
Chromium, 6·0 per cent.						
Steel 1F.—	500	84·5	94·7	9·0	24·8	—
Quenched in oil	600	46·3	56·8	17·8	50·1	29
from 875 deg. C.;	700	33·5	46·1	22·0	56·9	82
Chromium, 9·6 per cent.						
Steel 1G.—	500	—	105·0	8·6	24·0	8
Quenched in oil	600	57·1	64·1	14·8	41·8	15
from 900 deg. C.;	700	47·1	54·0	21·0	52·2	30
Chromium, 12·0 per cent.						
Steel 1H.—	500	67·5	84·5	4·0	5·1	—
Quenched in oil	600	44·1	59·0	13·5	37·6	37
from 875 deg. C.;	700	28·9	45·1	20·0	40·5	70
Chromium, 16·07 per cent.	750	31·5	47·3	23·0	49·7	58

so thoroughly understood that the mechanical properties of "stainless" materials are naturally affected by the

proportions of carbon which they contain. If the proportion of carbon is too high, the "stainless" properties may actually disappear, but that is the least interesting feature. The mechanical properties are distinctly altered by decreasing the proportion of carbon below that usually found in stainless steel. Not only are these properties altered, but many other accompanying characteristics are changed. The lower carbon materials are more easy to work in the forge and in the mill, whilst the relatively low air hardening properties which they display render them less prone to the development of surface defects during the operations of casting and hot-working.

The comparative ease with which the lower carbon forms of stainless material—which will henceforward be referred to as "stainless iron"—can be worked, renders it particularly suitable for the production of sheet, strip, wire, &c., as well as for the manufacture of comparatively intricate drop forgings. The tensile properties of the irons, as will be shown, are, in general, lower than those of the better-known stainless steels, but as the automobile engineer is usually satisfied with a comparatively moderate strength, the mechanical properties of the stainless iron are in almost all cases adequate for his requirements. When it is also remembered that this class of material should be purchaseable at a price which is lower than that of the better known stainless steel, the comparative value of the metal becomes quite high. In Table III the chemical composition of several different materials containing a stainless proportion of chromium are set out.

Table III.—*Chemical Composition of Series of High Chromium Steels and Irons.*

Mark.	Carbon.	Silicon.	Manganese.	Chromium.	Nickel.
	per cent.	per cent.	per cent.	per cent.	per cent.
2A	0·07	0·08	0·12	11·7	0·57
2B	0·07	0·32	0·29	13·3	0·40
2C	0·15	0·09	0·16	11·8	0·77
1G	0·37	0·19	0·15	12·0	0·55
2D	1·01	0·06	0·28	11·8	—

The mechanical properties of these materials are shown in Table IV., all the specimens of any one metal having been cooled in the most satisfactory manner from an appropriate temperature, and then having been tempered at different temperatures.

Table IV.—*Mechanical Properties of Series of High-Chromium Steels and Irons.*

—	Tempering Temperature, Deg. C.	Yield-Point, Tons per Sq. In.	Maximum Stress, Tons per Sq. In.	Elongation, per Cent.	Reduction of Area, per Cent.	Notched Bar, Ft.-Lb.
Iron 2A.—	—	66·8	73·2	13·5	41·9	28
Quenched in oil	200	68·4	73·0	12·0	37·8	33
from 930 deg. C.;	300	68·8	72·4	12·5	36·4	39
Carbon,	400	68·8	72·3	15·5	51·0	39
0·07 per cent.	500	58·8	72·4	18·0	52·2	36
	600	38·0	49·1	20·0	59·3	28
	700	30·6	40·4	26·5	65·8	79
	750	27·9	36·7	31·0	68·8	87
	800	33·6	53·6	13·5	44·6	51
Iron 2B.—	—	58·8	69·6	18·5	51·0	12
Quenched in oil	500	56·4	68·0	21·5	61·5	12
from 930 deg. C.;	600	35·2	45·6	25·5	71 8	92
Carbon,	750	36·6	38·6	34·0	68·8	110
0·07 per cent.						
Steel 2C.—	500	—	89·5	10·0	36·0	16
Quenched in oil	600	42·0	56·4	20·0	52·2	35
from 930 deg. C.;	700	38·0	46·8	26·0	58·1	60
Carbon,	750	31·2	43·9	28·0	61·5	68
0·15 per cent.						

For Steel 1G, see Table II. Carbon, 0·37 per cent.

Steel 2D.—	650	46·1	59·6	19·0	40·6	12
Cooled in air from	700	44·4	53·2	21·0	55·9	20
900 deg. C.;	750	36·8	50·0	24·0	47·2	23
Carbon,						
1·01 per cent.						

The effect of the carbon content of the material upon the mechanical properties of the steel or iron can be best seen by comparing the maximum stress of the different materials against their carbon content, as has been done in Table V and in the curves of Fig. 3.

Table V.—*Showing the Effect of Carbon Content on the Maximum Stress of High-Chromium Steels and Irons.*

Carbon, per Cent.	Maximum Stress (Tons per Sq. In.) after Tempering at			
	500 Deg. C.	600 Deg. C.	700 Deg. C.	750 Deg. C.
0·07	72·4	49·1	40·4	36·7
0·07	68·0	45·6	—	38·6
0·15	89·5	56·4	46·8	43·9
0·37	105·0	64·1	54·0	—
1·01	—	46·8a	44·4	36·8

a Tempered at 650 deg. C.

As indicating more definitely the fact that the component which has the greatest effect upon the mechanical properties of these steels is the carbon and not the chromium, the tests in Table VI may be quoted. These have been obtained upon a metal of the following composition :—

Mark.	Carbon.	Silicon.	Manganese.	Chromium.
	per cent.	per cent.	per cent.	per cent.
3A	0·11	0·14	0·09	4·72

Despite the equivalence of the mechanical properties of this iron with those of materials containing a higher proportion of chromium, the latter group will usually be preferred in practice because they possess the property of "stainlessness" which is not found in the lower chromium materials.

Table VI.—*Iron 3A. Quenched in Oil from 900 Deg. C.; Chromium, 4·72 per Cent.*

Tempering Temperature.	Yield-Point.	Maximum Stress.	Elongation.	Reduction of Area.	Notched Bar.
deg. C.	tons per sq. in.	tons per sq. in.	per cent.	per cent.	ft.-lb.
—	66·0	82·0	13·0	41·9	20
400	64·0	77·4	17·0	47·2	17
500	69·0	73·6	17·5	51·0	17
600	44·0	49·2	22·0	65·7	37
700	34·2	41·0	27·0	68·8	76
750	30·0	37·8	29·5	72·0	99
800	32·0	43·2	21·0	47·2	17

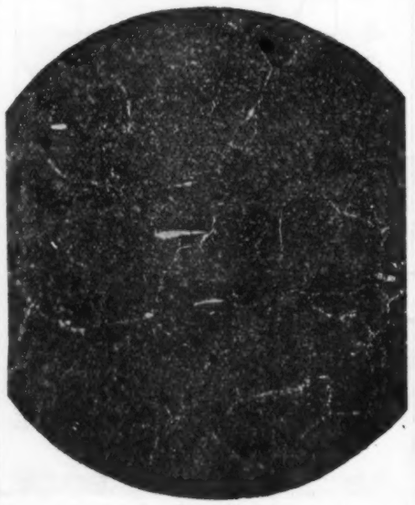


Fig. 5.

The tensile properties of the three representative mild materials 2A, 2C and 3A are indicated in Fig. 4, which shows clearly that the proportion of carbon, and not the chromium content, is the factor, which decides the mechanical properties of the heat-treated material, though not, of course, the "stainless" properties.

Before leaving the subject of the high-chromium steels and iron, it will be well to indicate the behaviour of the different metals when cooled in the air in order to emphasise the fact that the low-carbon group, *i.e.*, the irons, are less prone to harden when treated thus, than are the better-known "stainless" steels. In Table VII are set out the maximum stresses of the metals of different carbon content after cooling in the air.

Table VII

Mark.	Carbon.	Cooled in Air from	Maximum Stress.
	per cent.	deg. C.	tons per sq. in.
2B	0·07	930	58
2C	0·15	930	78
1G	0·37	930	110
2D	1·01	900	98
2D	1·01	1,000	106
3A	0·11	900	49

The iron 3A is included for comparison with 2B and 2C, to indicate that the proportion of chromium naturally affects the air hardening properties to some extent, though it is not so effective as the proportion of carbon.

For some years the chromium steels have been noted for the way in which they resist wear, even when that wear is distinctly heavy. This has given them a considerable vogue for the manufacture of parts such as ball races, in which a high resistance to abrasion is of great value. It has been customary for a long time to employ as a basis for hard materials those plain carbon steels which had previously given good service in tools, and which were known to be hard and capable of putting up a good performance under conditions which demanded a good resistance to abrasion. These steels usually contained about 1 per cent. of carbon. It was found that if such steels were provided with a proportion of an alloying element such as chromium, their resistance to abrasion, which was already high, was notably increased, as was the hardness of the metal as judged by the Brinell test. This was particularly true when the section under treatment was moderately large. The proportion of the alloying element which needed to be present was not high—about 1 per cent. or 1·5 per cent., and the resulting steel was, and is, quite satisfactory. The mechanical properties of a steel of this kind are shown later.

In connection with this class of steel, a point of some importance arises in regard to the structure and its effect upon the properties of the material. It is generally appreciated that plain carbon steels containing more than about 0·85 per cent. of carbon, contain, as a microscopic constituent, free carbide of iron. This carbide of iron usually enmeshes the crystals of the steel, and is generally found in this position even after the steel has been hardened in the usual commercial manner, because the hardening temperature is not sufficiently high to take the carbide into solution.

Since the carbide lies around the crystals of the steel it tends to make the metal brittle. Its action in this direction can be understood when it is realised that in a great measure the carbide effectively separates the crystals of metal from one another, and hence provides paths along which any crack, once started, may spread with considerable ease. (The danger is similar to that which exists in case-hardened parts which have been over-carburised, and which in consequence contain free carbide of iron.)

If the steel contains chromium this free carbide is still produced (though it is not necessarily of the same composition as the carbide in plain carbon steels). In such steels, however, the proportion of carbon need not be as high as 0·85 per cent. in order to produce a proportion of free carbide in the steel. With 1 per cent. or 1·5 per cent. of chromium a steel containing about 0·75 per cent. of carbon will contain a little free carbide, and the proportion of this constituent increases with the proportion of carbon which is present. In view, therefore, of the dangerous nature of this constituent, it is desirable, provided that no consequent harm is done to the mechanical properties, to keep the carbon content of the steel as near to 0·75 per cent. as possible. The structure of a chromium steel containing about 0·85 per cent. of carbon and therefore containing free carbide is shown in Fig. 5.

The mechanical properties of a typical low-carbon steel suitable for ball bearings are shown in Table VIII. The chemical composition of the steel tested was as follows :—

Carbon.	Silicon.	Manganese.	Sulphur.	Phosphorus.	Chromium.
per cent.	per cent.	per cent.	per cent.	per cent.	per cent.
0·75	0·16	0·34	0·034	0·035	1·29

Table VIII.—*The Mechanical Properties of a "Ball Race" Steel.*

Tempering Temperature.	Yield-Point.	Maximum Stress.	Elongation.	Reduction of Area.	Notched Bar.
deg. C.	tons per sq. in.	tons per sq. in.	per cent.	per cent.	ft.-lb.
—	—	132·0	—	—	—
500	82·8	88·7	10·0	27·6	9
600	63·6	70·8	17·0	45·9	25
650	55·2	63·5	20·0	51·0	38
700	52·3	59·6	21·0	52·2	48
750	39·1	53·7	26·0	58·0	38

When considering the chromium steels, it is necessary to take some note of those chromium steels to which some vanadium has been added. Various advantages are claimed for steels of this type. It is often stated that the steels having vanadium as a constituent are stronger than those free from that element, that they are sounder and more homogeneous, and that they have a higher fatigue strength. As regards the last, the claim has been tested directly, with the result that it has not been substantiated. The second claim is distinctly difficult to test and may or may not be accurate. The first claim is easy to put to the test.

It can be admitted at once that vanadium does exert an influence upon the mechanical properties of steel, and it can be admitted also that the addition of this element will tend to raise the tensile strength of the steel in which it is found. What has to be shown, however, is that the addition of strength resulting from the addition of the vanadium is commensurate with the cost of the element. When this view is taken, it becomes clear that, for a successful result to be obtained, the efficacy of vanadium would need to be about 40 times as great as that of chromium, unless, of course, the vanadium actually conferred properties which chromium was unable to impart. That the vanadium does not do this can be seen from the results shown in Table X.

The steels tested consist of two pairs, one pair having a medium low proportion of carbon, and the other a medium high proportion of carbon. One member of each pair contained a normal proportion of vanadium, whilst the second member was free from vanadium but contained a rather higher proportion of chromium than the first

member. The actual chemical compositions are shown in Table IX.

TABLE IX.

Mark.	Carbon.	Silicon.	Manganese.	Chromium.	Vanadium.
	per cent.	per cent.	per cent.	per cent.	per cent.
4A	0·42	0·21	0·75	1·04	0·15
4B	0·45	0·12	0·72	1·28	nil
4C	0·29	0·16	0·69	1·0	0·19
4D	0·31	0·14	0·75	1·36	nil

The mechanical properties of the steels were as follows:

TABLE X.

—	Tempering Temperature, Deg. C.	Yield-Point, Tons per Sq. In.	Maximum Stress, Tons per Sq. In.	Elongation, per Cent.	Reduction of Area, per Cent.	Notched Bar, Ft.-Lb.
Steel 4A.— Quenched in oil from 870 deg. C.; containing Vanadium.	400	68·4	83·0	13·5	49·8	16
	500	75·4	80·9	11·0	47·3	22
	600	62·3	70·5	15·0	51·1	19
	650	59·2	65·0	18·7	55·2	77
	700	44·9	52·2	25·5	62·0	90
	750	39·3	46·2	30·5	68·7	118
Steel 4B.— Quenched in oil from 860 deg. C.; free from Vanadium.	300	104·0	117·2	3·2	8·3	2
	400	85·3	99·2	9·0	32·9	4
	500	70·0	80·1	3·7	45·3	10
	600	58·5	64·6	20·0	54·1	21
	650	49·8	58·1	23·0	60·8	43
	700	41·6	51·1	26·0	64·3	88
	750	32·3	47·1	30·5	69·8	96
Steel 4C.— Quenched in oil from 860 deg. C.: containing Vanadium.	300	51·0	70·0	10·8	50·9	10
	400	52·4	65·6	17·0	57·5	15
	500	55·3	63·5	18·0	56·8	20
	600	51·1	59·1	21·0	59·8	23
	650	48·6	55·2	22·0	63·9	15
	700	43·6	50·6	22·5	65·8	66
	750	37·7	42·1	30·2	68·8	110
Steel 4D.— Quenched in oil from 860 deg. C.; free from Vanadium.	300	65·0	71·6	12·7	45·9	3
	400	69·0	74·0	11·7	43·2	3
	500	53·4	62·0	16·0	55·8	10
	600	48·0	59·2	21·0	62·5	17
	650	42·3	54·3	23·0	66·0	52
	700	35·7	45·0	23·0	67·9	90
	750	29·6	40·5	31·5	70·7	93

The general result of the test figures quoted is that the mechanical advantage produced by the addition of vanadium to steel can be obtained equally satisfactorily by the addition of chromium. It actually appears that the mechanical properties of a chromium-vanadium steel are due mainly to the chromium and only a little to the vanadium, and that the additional effect produced by the vanadium content of the steel can be equally well obtained by the addition of a somewhat larger proportion of chromium.

The conclusions to be drawn from this very brief examination of the chromium steels and irons appear to be as follows:—

(1) That chromium steels can be obtained which possess the mechanical properties desired by the automobile engineer for structural or for engine work. For such ordinary purposes the proportion of chromium which must be present need not be high. If 3 per cent. of chromium is added, the requisite mechanical properties, as well as a fairly good resistance to the effect of mass in hardening, can be obtained. For quite small parts, and for heat-treated bars of small diameter, the proportion of chromium need not be so high even as this—1 per cent. to 1·5 per cent. of that element being sufficient.

(2) That in steels containing a medium proportion of carbon the influence of the proportion of chromium upon the mechanical properties of the material is at first great, rising rapidly to a maximum which holds for a considerable distance, after which there is a slight falling away. This can be readily seen from the test results obtained upon the first series of steels.

(3) That the influence of the proportion of carbon in the steel is very great, and that it overshadows the influence of the chromium very much. This applies both to the steels with a low, and those with a high, proportion of chromium.

(4) That, for purposes in which "stainless" properties as well as good mechanical properties are valuable, there is a considerable range of materials to hand. The mechanical requirements of the automobile engineer are likely to be met fully by the "stainless" irons, and these materials are quite as "stainless" as—if not more so than—the high-carbon "stainless" steels. Such material is very much easier to work than the higher-carbon materials, and can be obtained readily in more usable forms.

(5) That the mechanical advantages of the addition of vanadium to chromium steels are not apparent.

The author wishes to tender his thanks to Mr. Harry Brearley for his kindness in allowing him to have access to the many test results that he has obtained on chromium steels and stainless irons.

APPENDIX A.

In Table XI test results given indicate more fully the mechanical properties of the lower-chromium steels—*i.e.*, the steels that are likely to be employed by the engineer in consequence of their mechanical properties alone—for structural or engine work.

TABLE XI.

—	Tempering Temperature, Deg. C.	Yield-Point, Tons per Sq. In.	Maximum Stress, Tons per Sq. In.	Elongation, per Cent.	Reduction of Area, per Cent.	Notched Bar, Ft.-Lb.
Steel 1B.— Carbon, 0·45 per cent.; Chromium, 1·28 per cent. Cooled in air from 870 deg. C.	—	31·3	53·4	22·0	60·8	2
	400	31·2	53·8	23·2	61·0	3
	500	31·3	53·2	23·2	61·5	3
	600	30·0	52·5	23·5	61·5	3
	650	29·0	51·7	23·5	61·5	5
	700	26·6	48·7	25·0	61·0	4
	750	26·1	45·9	27·5	63·6	6
Steel 1B.— Quenched in oil from 870 deg. C.	300	104·0	107·2	3·2	8·3	2
	400	85·3	99·2	9·0	32·9	5
	500	70·0	80·1	13·7	45·3	10
	600	58·5	64·6	20·0	54·1	21
	650	49·8	58·1	23·0	60·8	42
	700	43·2	52·0	26·0	63·7	88
	750	32·3	47·1	30·5	69·8	98
Steel 1C.— Carbon, 0·37 per cent.; Chromium, 2·8 per cent. Cooled in air from 830 deg. C.	—	62·0	80·0	13·5	26·1	12
	100	58·0	78·8	15·0	29·1	12
	200	66·8	81·2	13·5	30·6	11
	300	68·0	81·2	13·5	39·2	4
	400	68·4	77·6	14·0	39·2	7
	500	61·0	72·0	16·0	45·9	7
	600	47·6	56·0	21·0	61·5	36
	700	38·8	48·8	25·5	66·8	98
Steel 1C.— Quenched in oil from 830 deg. C.	400	90·0	92·4	13·0	43·2	6
	500	79·4	81·3	10·5	27·6	9
	600	56·0	61·6	20·0	60·4	28
	650	47·0	54·4	24·0	62·6	92
	700	41·2	49·4	25·0	67·8	98
	750	37·4	44·0	29·0	70·8	111

APPENDIX B.

It would not be fitting for a paper on chromium steels and irons to be written which made no mention of the stainless properties of these materials. Nevertheless it seems unnecessary to go into this subject in detail, since many other writers have dealt with this aspect of these metals.

The property of true stainlessness is conferred upon most ferrous materials by the presence of 11 per cent. to 14 per cent. of chromium. The actual proportion of chromium that is necessary to produce these properties depends to some extent upon the proportion of carbon that is present, and in general it may be taken that if the carbon is lowered very definitely the proportion of chromium that is necessary can be reduced also.

The constitution of the material considerably affects the degree of stainlessness which it possesses. This means that the way in which the metal is heat-treated affects the property of stainlessness. Material which is in its hardened state is definitely the most resistant to staining. If the material is tempered it gradually becomes somewhat less resistant to staining, though even after tempering at about 650 deg. to 700 deg. C. it resists rusting very successfully. If it is normalised its resistance to staining is impaired very considerably, but nevertheless it is still strongly resistant to rusting.

The resistance to staining and rusting should not be confused with resistance to scaling. As a matter of fact the chromium steels and irons resist scaling (*i.e.*, oxidation in a non-reducing atmosphere) very satisfactorily—particularly at the higher temperatures. It is not necessary, however, to have quite such a high proportion of chromium in the steel to produce a high resistance to scaling as to produce a notable degree of stainlessness, and with only 7 per cent. or 8 per cent. of chromium the resistance to scaling is considerable. With both this material and that which contains a stainless proportion of chromium the scale which does form is particularly adherent and close, and shows practically no tendency to flake or shale off.

ALUMINIUM CHART.—The British Aluminium Company, Limited, whose London offices are at 109, Queen Victoria-street, E.C. 4, have issued a chart giving weights, dimensions in inches and in the metric system, areas, electrical data, &c., concerning aluminium tubes, bars and strips, sheet, wire, strand, rods, and the physical and mechanical properties as compared with brass and steel. They have a number of other publications dealing with their specialities.

GERMAN ENTERPRISE IN THE DUTCH INDIES.—German trade connections did not come to an end with the war, and they are now being resumed with much energy in various quarters of the globe. Considerable commotion has been caused in Holland on it transpiring that a German industrial syndicate, under the control of Hugo Stinnes, had succeeded in securing an important concession from the Government of the Dutch Indies for the construction there of large factories for the manufacture of rolling stock, railway bridges, &c., the Government having complied with a condition laid down by the syndicate, namely, the placing of a substantial guaranteed order from the Government for the products of the new factories. Some natural annoyance has been caused in Holland by this concession having been granted to a foreign concern, without making any inquiries as to whether the plant in question could be produced in the home country at similar prices. The matter has been brought before the Dutch Diet, and the Minister in charge could only confirm the correctness of the statement; he said that the undertaking would have to be upheld, but no future or further orders would in the meantime be given to foreigners.

CATALOGUES.

Shearing Machines.—A number of powerful hydraulic shearing machines for cutting billets, plates and slabs, are described in a catalogue issued by Messrs. Duncan Stewart and Co., Limited, London-road, Glasgow.

Electric Motors.—A catalogue of motors intended for driving printing machines is to hand from Messrs. Swedish General Electric, Limited, 5, Chancery-lane, London, W.C. 2, together with lists of motors in stock.

Signalling Apparatus.—An apparatus for sending and acknowledging signals in power stations and their branches is dealt with in a catalogue received from Messrs. Siemens Brothers and Co., Limited, Woolwich, London, S.E. 18.

Condensers.—Two leaflets giving very striking illustrations of a surface condenser with 10,000 sq. ft. of cooling surface and a steam ejector air pump suitable for a 12,500-kw. high-pressure turbine, have come from the Mirrlees Watson Company, Limited, Scotland-street, Glasgow.

Cranes.—A number of cranes and hoists, mostly for heavy duty lifting, are shown in a 32-page catalogue received from the Harbour Improvement and Mechanical Engineering Company, Limited, 53, New Broad-street, London, E.C. 3. These are made at the Figee Works, Haarlem.

Milling Cutters.—The catalogue of high-speed steel milling cutters issued by Messrs. Samuel Osborn and Co., Limited, Sheffield, deals with all the principal standard forms, including hobs and gear-tooth cutters in an extensive range of sizes. The lists give the working dimensions and prices.

Tool Steels.—A small catalogue of tool and special alloy steels received from Messrs. John Nicholson and Sons (Sheffield), Limited, gives a list of steels with very practical notes for the guidance of tool makers in forging and heat treatment. The booklet deals with steels for dies, magnets, valves, &c., as well as for all usual tools.

Tank Parts.—Standard parts for building tanks of varying sizes are described in a catalogue received from Messrs. Thomas Piggott and Co., Limited, Spring Hill, Birmingham. The plates are made of steel with ribs and flanges formed by pressure. Corner pieces, bolts, stays, jointing material, and tools for quick erection, are supplied if required.

Compressors.—The rolling drum air compressor made by Messrs. Reavell and Co., Limited, Ipswich, is described in a catalogue received recently. For pressures up to 15 lb, it is an extremely simple and durable machine suitable for direct drive by motor. A good range of standard sizes is listed, and particulars are given of the volume delivered and horse-power required by each machine.

Sherardising Protection.—A pamphlet describing the dry vapour galvanising, or sherardising, process, by which a coating of zinc can be applied to iron or steel is worthy of attention, as the process is simple, suitable for small quantities or occasional use, and workable at a temperature which will not affect the temper of steel. The plant is made by the Cowper-Coles Manufacturing Company, Sunbury-on-Thames.

Oil Engines.—A fine series of vertical oil engines working on crude, refined or intermediate fuel oils, and ranging in power from 30 b.h.p. to 300 b.h.p., is described in a catalogue received from Messrs. Marshall, Sons and Co., Limited, Gainsborough. Two types are dealt with for land and marine work respectively. Single-cylinder engines of the land type are supplied with extra heavy flywheels, to ensure steady running for the production of lighting current where no accumulators are used.

Storage Tanks for Petrol, Oil, &c.—A system of storage, including tanks buried underground, for petrol, oil, paint, and similar liquids, complete with pumping, indicating, venting and other appliances, is described in a catalogue received from the Dowson and Mason Gas Plant Company, Limited, 3, Manchester-street, London, W. 1. The pump is of the measuring type, and one of these entirely cased in, and suitable for erection on the public thoroughfare is shown. We illustrated and described one of these plants in our issue of November 4 last, on page 632.

Disinfector.—The sack disinfector for clothing, &c., utilises an inverted sack or fabric tube into which clothing suspended on hooks can be drawn. A blast of steam is then applied and the clothing, being very hot when taken out, dries quickly. Ten suits can be treated and dried in 10 minutes, or 1,000 army blankets in 8 hours. The cost of the apparatus and fuel is very low. Messrs. Meldrums, Limited, Timperley, Manchester, have issued a catalogue of this apparatus which will be of considerable interest to the medical and sanitary officers of local authorities.

Motor Vehicles.—A very complete and handsome catalogue of motor vehicles is to hand from Messrs. J. I. Thornycroft and Co., Limited, 10, Grosvenor-place, London, S.W. 1. These vehicles are of 30 h.p. and 40 h.p., and are supplied complete with all types of bodies for goods or passenger service, as well as with hoisting, tipping or other special auxiliary gear as required; they can also be supplied with electric lighting or starting sets. The engines run on petrol or, by using a special vapouriser, on paraffin. The catalogue gives a fully detailed description of parts written in a very clear and informing style and contains ample illustrations of complete vehicles and parts, and also with diagrams of 15 standard types of bodies made by the firm.

"ENGINEERING" ILLUSTRATED PATENT RECORD.

SELECTED ABSTRACTS OF RECENT PUBLISHED SPECIFICATIONS UNDER THE ACTS OF 1907 AND 1919.

The number of views given in the Specification Drawings is stated in each case; where none is mentioned the Specification is not illustrated.

Where inventions are communicated from abroad, the Names, &c., of the communicators are given in italics.

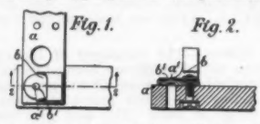
Copies of Specifications may be obtained at the Patent Office, Sales Branch, 25, Southampton Buildings, Chancery-lane, London, W.C., at the uniform price of 1s.

The date of the advertisement of the acceptance of a Complete Specification is, in each case, given after the abstract, unless the Patent has been sealed, when the word "Sealed" is appended.

Any person may, at any time within two months from the date of the advertisement of the acceptance of a Complete Specification, give notice at the Patent Office of opposition to the grant of a Patent on any of the grounds mentioned in the Acts.

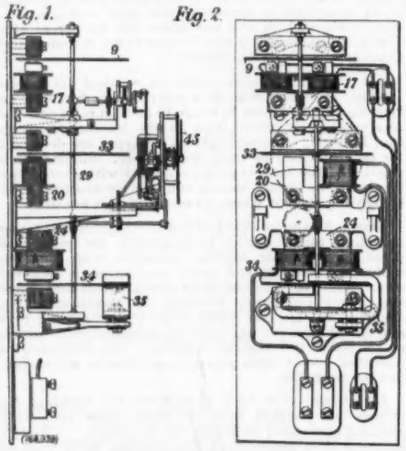
ELECTRICAL APPARATUS.

168,363. J. B. Tucker, Birmingham, and J. H. Tucker and Co., Limited, Birmingham. Electric Contacts. (2 *Figs.*) May 20, 1920.—The invention comprises an electric contact having a base adapted to be secured to a bus-bar, in which rotation of the contact in relation to the bus-bar is avoided by key provision comprising a pillar or stud produced by a partial



punching of a piece out of the bus-bar. The bus-bar *a* is formed with an upward projection *a*1, which engages within a perforation *b*1 in the contact *b*. The projection *a*1 is produced by a punching operation which drives in the metal at the back of the bus-bar *a* and causes it to project on the other face to constitute a pillar or stud. (*Accepted September* 14, 1921.)

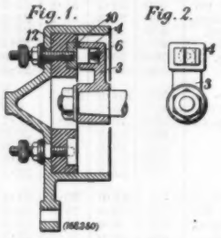
168,339. G. F. Shotter, Streatham, and E. W. Hill, Stoke Newington. Alternating Current Electrical Instrument. (2 *Figs.*) March 3, 1920.—An ampere-hour meter for alternating current comprises an unsaturated main shaded pole electromagnet 24 connected in series with the load, a rotatable metal disc 34 in proximity to the poles thereof, a permanent magnet 35 with its poles close to the disc, and counting or recording mechanism to count or record the revolutions of the disc. A second shaded pole electromagnet may be disposed with its poles in proximity to the disc 34 and connected across the terminals of the electric supply, to impart a small constant torque to the disc to urge it in the same direction as does the torque due to the main shaded pole electromagnet 24. A third electromagnet 20 may be provided with its poles in proximity to the disc 34 connected either in series with the main shaded pole electromagnet 24 or in parallel therewith and without any shading of the poles. This magnet produces no driving torque on the disc, but it serves as a further means to retard the disc, and it is designed so that at top loads it is saturated to such an extent that the total retarding torque on the disc at top loads causes the speed to vary directly with the current. The speed of rotation of the disc is, above a certain value, proportional to the current flowing through the coils of the main shaded pole electromagnet 24, and therefore the counting mechanism driven by



the disc spindle will register ampere-hours. The second shaded pole electro-magnet will contribute towards obtaining proportionality between the current flowing through the coils of the main shaded pole electromagnet 24 and the speed of rotation of the disc 34. By substituting for the simple counting mechanism a demand indicator, for example of the kind in which a non-return pointer 45 is pushed over a scale by a pin moved by the rotation of the disc 34, and in which the pin is disconnected from its driving means at intervals and is returned to its original position, under the action of a spring, the instrument becomes an average maximum demand ampere meter; and by arranging the scale over which the pointer moves so that consideration is taken of the voltage of the supply, the instrument may be made to read the average maximum demand in kilo-volt-amperes on an alternating current supply. The main shaded pole electromagnet 24 and constant flux magnet 35 may operate on one disc 34 and the second shaded pole electromagnet, to produce a small constant driving torque and/or the retarding electromagnet 20 may operate on a second disc 33, both discs being mounted on a common spindle 29. A shaded pole electromagnet 17 connected across the terminals of the alternating current supply and acting on a rotatable disc 9, is employed instead of clock mechanism to disconnect from its driving mechanism, at regular intervals, the pin which drives the pointer 45 and allow it to return to a zero position. The speed of the disc 9 varies with the frequency and thus compensation is provided for inaccuracies due to the variation of frequency of the current energising the main shaded pole electromagnet 24. (*Sealed.*)

GAS ENGINES, PRODUCERS, HOLDERS, &c.

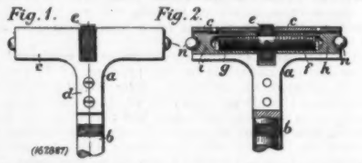
168,350. A. W. Fellows, Blisworth and W. A. Gardner, Towcester. Internal-Combustion Engines. (3 *Figs.*) June 5, 1920.—The brush of the distributing device for the ignition systems of internal-combustion engines is, according to this invention, constructed with an electrical collector portion and a cleaning portion housed together so as to bear on the same



track. The distributing arm has, at its outer end, a recessed boss 4 which contains a brush that is urged outwardly by a spiral spring 6. The brush is composed of layers of carbon, copper gauze and felt pinned together. The brush contacts with metal studs 10 mounted in a disc or ring 12 of insulating material. (*Accepted September* 14, 1921.)

MACHINE AND OTHER TOOLS, SHAFTING, &c.

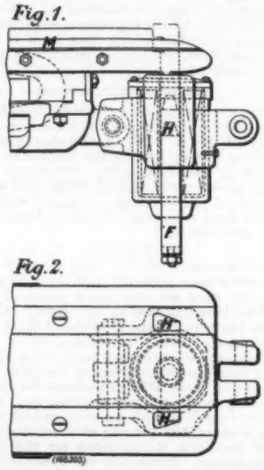
167,887. R. J. Austin, Birmingham, and P. B. Newell, Birmingham. Gauges. (6 *Figs.*) May 27, 1920.—The improved gauge comprises a body with a T-head which is tubular and formed as a clip adapted to receive and clamp in position therein adjustable gauge pieces. A feature of the invention is the simultaneous operation of the gauge pieces. A convenient embodiment of the invention comprises a stock *a* having a handle *b* and a T-shaped head *c*. This head is in the form of a split tubular clip having a part *d* overlapping part of the stock and adapted to be screwed against the same to reduce the diameter of the tubular



clip portion. Centrally arranged in the head of the stock is a knurled collar *e*, arranged for free rotation. Passing axially through this collar, and secured to it, is a screw rod having oppositely-threaded portions *f*, *g*, which enter correspondingly-threaded gauge sleeves *h*, *i*. As the knurled collar *e* is rotated, the gauge sleeves are adjusted outwardly or inwardly simultaneously. The sleeves *h*, *i* may be prevented from turning in the stock, whilst being free for axial movement. The ends of the sleeves are provided with balls *n*, each soldered in a recess in the end of the sleeve, to provide a point contact for the gauge pieces (*Sealed.*)

MINING, METALLURGY AND METAL WORKING.

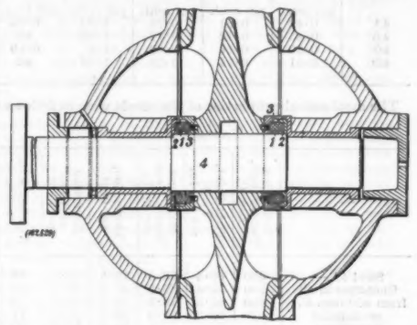
168,393. David Colville and Sons, Limited, Motherwell, and J. F. Inglis, Motherwell. Plate-Handling Skids. (2 *Figs.*) May 29, 1920.—The invention relates to skids for handling plates in connection with rolling mills of the kind in which there is a plate-receiving table upon which the plate is held electromagnetically, the skid table being used to convey the plates over that part of the cooling floor which is between carrying or conveying rollers on opposite sides of that floor. The rollers on one side take the plates at a red heat, and those on the other



side convey the cold plates to shearing or like machines. To retain the plate upon the table and prevent its displacement off the magnet when the plate is too hot to be magnetic, means are provided, according to this invention, comprising essentially a plunger H, normally below the level of the table M, operatively connected to a solenoid core F, movable with the table M, adapted to raise it above the surface of the table and into the path of the plate, so that the plate will be conveyed when the table is moved without the table magnets being energised. (*Accepted September* 14, 1921.)

PUMPS.

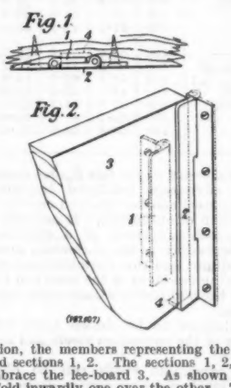
167,529. A. T. Cottor, Fleetwood, and William Simons and Co., Limited, Renfrew. Centrifugal Pumps. (3 *Figs.*) April 9, 1920.—Shaft bearings, *e.g.*, for centrifugal and like pumps, for dredging cutters and other devices, are protected against the ingress of sand, grit or the like material to the bearings, by the provision of a deformable annulus or annuli of rubber



adapted to be initially compressed and enclosed, wholly or partly, between rings of channel section surrounding the shaft or a liner on the shaft. 1, 1 denote annuli of rubber, each enclosed between a pair of rings 2, 3 of channel section of anti-friction metal, having bearing contact with the shaft 4. (*Accepted August* 24, 1921.)

SHIPS AND NAUTICAL APPLIANCES.

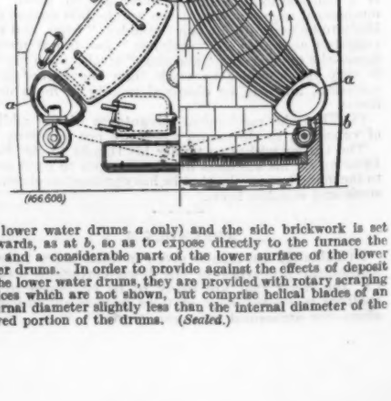
167,107. W. McGeoch and Co., Limited, Glasgow, and W. McGeoch, Glasgow. Lee-Board Fittings. (3 *Figs.*) October 1, 1920.—It has heretofore been the practice to accommodate the lee-board in a slot formed between outwardly-projecting wings embracing the ends of the lee-board. According



to this invention, the members representing the slot are each made in hinged sections 1, 2. The sections 1, 2, when turned outwardly, embrace the lee-board 3. As shown in Fig. 1, the sections 1, 2 fold inwardly one over the other. The innermost folding section 1 and a projecting ledge 4, at the lower end of the folding section 2, are accommodated in a recess. (*Sealed.*)

STEAM ENGINES, BOILERS, EVAPORATORS, &c.

166,608. R. Baillie, Glasgow. Water-Tube Steam Generators. (1 *Fig.*) February 4, 1920.—The volume of the furnace and the heat-absorbing surface exposed thereto are increased without increasing the normal external dimensions of water-tube steam generators of the Yarrow type, by exposing the lower water drum or drums directly to the furnace, and providing in such exposed drum or drums a rotary scraping element. In carrying the invention into effect, the boiler is raised bodily (or



the lower water drums *a* only) and the side brickwork is set outwards, as at *b*, so as to expose directly to the furnace the side and a considerable part of the lower surface of the lower water drums. In order to provide against the effects of deposit in the lower water drums, they are provided with rotary scraping devices which are not shown, but comprise helical blades of an external diameter slightly less than the internal diameter of the curved portion of the drums. (*Sealed.*)